This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

WIDENER LIBRARY
HX HHN4 P

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS 1905

Harvard University

LIBRARY OF THE

DIVISION OF
ENGINEERING

HARVARD COLLEGE

SCIENCE CENTER
LIBRARY

TRANSACTIONS

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

VOLUME I

First Meeting, New York, N. Y., 1905
December 4 and 5

PUBLISHED BY THE SOCIETY
FROM ITS OFFICES, SUITE 806, No. 258 BROADWAY
NEW YORK, N. Y.

1906

Sci 1520.517

2 Mar 1910
HARVARD UNIVERSITY
DEPARTMENT OF ENGINEERING.
(I-III)

Jul. 1, 1919
Transferred to
Harvard College Library

Organized December 5, 1904, at New York, N. Y.

Incorporated under the Laws of the State of New York
August 30, 1905

Copyright, 1906
By The American Society of Refrigerating Engineers

OFFICERS

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

1904–1905.

PRESIDENT.

JOHN E. STARR.....New York, N. Y.

VICE-PRESIDENTS.

H. B. ROELKER.....New York, N. Y.

Term expired at Annual Meeting of 1905.

P. D. C. BALL.....St. Louis, Mo.

Term expires at Annual Meeting of 1906.

DIRECTORS.

LOUIS BLOCK.....New York, N. Y.
W. EVERETT PARSONS.....New York, N. Y.
EDGAR PENNEY.....Newburgh, N. Y.

Terms expired at Annual Meeting of 1905.

ELLIS L. PHILLIPS.....New York, N. Y.
D. S. JACOBUS.....Hoboken, N. J.
W. T. ROBINSON.....Philadelphia, Pa.

Terms Expire at Annual Meeting of 1906.

HENRY TORRANCE, JR.....New York, N. Y.
THOMAS SHIPLEY.....York, Pa.
L. HOWARD JENKS.....New York, N. Y.

Terms Expire at Annual Meeting of 1907.

TREASURER.

WALTER C. REID.....New York, N. Y.

SECRETARY.

WILLIAM H. ROSS.....New York, N. Y.

OFFICERS

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

1905–1906.

PRESIDENT.

W. EVERETT PARSONS.....New York, N. Y.

VICE-PRESIDENTS.

P. D. C. BALL.....St. Louis, Mo.
Term expires at Annual Meeting of 1906.

JOHN E. STARR.....New York, N. Y.
Term expires at Annual Meeting of 1907.

DIRECTORS.

ELLIS L. PHILLIPS.....New York, N. Y.
D. S. JACOBUS.....Hoboken, N. J.
W. T. ROBINSON.....Philadelphia, Pa.
Terms Expire at Annual Meeting of 1906.

HENRY TORRANCE, JR.....New York, N. Y.
THOMAS SHIPLEY.....York, Pa.
L. HOWARD JENKS.....New York, N. Y.
Terms Expire at Annual Meeting of 1907.

LOUIS BLOCK.....New York, N. Y.
EDGAR PENNEY.....Newburgh, N. Y.
H. B. ROELKER.....New York, N. Y.
Terms Expire at Annual Meeting of 1908.

TREASURER.

WALTER C. REID.....New York, N. Y.

SECRETARY.

WILLIAM H. ROSS.....New York, N. Y.

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

CONSTITUTION.

NAME, OBJECT AND GOVERNMENT.

C 1. The title of this Society shall be "The American Society of Refrigerating Engineers."

C 2. The object of this Society is to promote the Arts and Sciences connected with Refrigerating Engineering.

C 3. The principal means for this purpose shall be the holding of meetings for the reading and discussion of appropriate papers, and for social intercourse; the publication and distribution of its papers and discussions; and the maintenance of a library of data on refrigeration.

C 4. The Society shall be governed by this Constitution, and by By-Laws and Rules in harmony therewith.

C 5. The Society shall be organized as a Corporation under the laws of the State of New York.

MEMBERSHIP.

C 6. Persons connected with the Arts and Sciences relating to Refrigerating Engineering may be eligible for admission into the Society.

C 7. The membership of the Society shall consist of Members, Associates and Juniors. Members and Associates are entitled to vote and to hold office. Juniors shall not be entitled to vote nor to be officers of the Society, but shall be entitled to the other privileges of membership.

C 8. Members and Associates are entitled to vote on all questions before any meeting of the Society, in person or by proxy, given to a voting member in writing. A proxy shall not be valid for a greater time than six months.

C 9. A Member shall be twenty-six years of age or over. He must have been so connected with Refrigerating Engineering as to be competent as a designer or as a constructor, to take responsible charge of work in his branch of Refrigerating Engineering, or he

must have served as a teacher of Refrigerating Engineering for more than five years.

C 10. An Associate shall be twenty-six years of age or over and shall be so connected with Refrigerating Engineering as to be competent to take charge of engineering work, or to co-operate with Refrigerating Engineers.

C 11. A Junior shall be twenty-one years of age or over. He must have had such Refrigerating Engineering experience as will enable him to fill a responsible subordinate position in Refrigerating Engineering work, or he must be a graduate of an engineering school.

C 12. The rights and privileges of every Member, Associate and Junior shall be personal to himself, and shall not be transferable or transmissible by his own act or by operation of law.

ADMISSION.

C 13. All applications for membership as Member, Associate or Junior shall be presented to the Council, which shall consider and act upon each application, assigning each approved applicant to the classification to which, in the judgment of the Council, he is entitled. The name of each candidate thus approved by the Council shall, unless objection is made by the applicant, be submitted to the voting membership for election by means of a letter ballot.

C 14. Associates or Juniors desiring to change their grade of membership shall make application to the Council in the same manner as is required in the case of a new applicant.

C 15. Election to membership shall be by a sealed letter ballot as the By-Laws shall provide. Adverse votes to the number of four per cent. of the votes cast shall be required to defeat the election of an applicant.

C 16. Each person elected shall subscribe to this Constitution, and shall pay the initiation fee before he can be entitled to the rights and privileges of membership. If such person does not comply with these requirements within six months after notice of his election he will be deemed to have declined election. The Council may, thereupon, declare his election void.

INITIATION FEES AND DUES.

C 17. The initiation fee for membership shall be as follows:

For Members and Associates five dollars.

For Juniors five dollars.

A Junior on promotion to any other grade of membership shall pay an additional fee of five dollars.

The annual dues for membership shall be as follows:

For Members and Associates ten dollars.

For Juniors five dollars for the first six years of their membership, and thereafter the same as for a Member or Associate.

SUSPENSIONS AND EXPULSIONS.

C 18. Any Member, Associate or Junior who shall leave his annual dues unpaid for two years shall, at the discretion of the Council, have his name stricken from the roll of membership and shall cease to have any further rights of membership.

C 19. The Council may refuse to receive the dues of any Member, Associate or Junior who shall have been adjudged by the Council to have violated the Constitution or By-Laws of the Society, or who, in the opinion of the Council expressed by a two-thirds vote of the entire Council, shall have been guilty of conduct rendering him unfit to continue in its membership; and the Council may expel such person and remove his name from the list of members.

THE COUNCIL.

C 20. The affairs of the Society shall be managed by a Board of Directors chosen from among its Members and Associates, which shall be styled "The Council." The Council shall consist of the President of the Society, who shall be presiding officer; the two Vice-Presidents, Treasurer and nine Members or Associates. Seven Members of the Council shall constitute a quorum for the transaction of business. The Secretary may take part in the deliberations of the Council, but shall not have a vote therein.

C 21. The Council thus constituted shall regulate its own proceedings and shall be the legal Trustee of the Society. All gifts or bequests not designated for a specific purpose shall be invested by the Council, and only the income therefrom may be used for current expenses.

C 22. Should a vacancy occur in the Council, or in any elective office except the presidency, through death, resignation or other cause, the Council may elect a Member or Associate to fill the vacancy until the next annual election.

C 23. The Council shall present at the Annual Meeting of the Society a report verified by the President or Treasurer or by a majority of the members of the Council, showing the whole amount of real

and personal property owned by the Society, where located, and where and how invested, and the amount and nature of the property acquired during the year immediately preceding the date of the report, and the manner of the acquisition; the amount applied, appropriated or expended during the year immediately preceding such date, and the purposes, objects or persons to or for which such applications, appropriations or expenditures have been made; also the names and places of residence of the persons who have been admitted to membership in the Society during the last year, which report shall be filed with the records of the Society, and an abstract thereof shall be entered in the minutes of the proceedings of the Annual Meeting.

C 24. An act of the Council which shall have received the expressed or the implied sanction of the membership at the next subsequent meeting of the Society shall be deemed to be the act of the Society, and shall not afterward be impeached by any member.

C 25. The Council may, by a two-thirds vote of the members present, declare any elective office vacant, on the failure of its incumbent for one year, from inability or otherwise, to attend the Council meetings, or to perform the duties of his office, and shall thereupon appoint a Member or Associate to fill the vacancy until the next Annual Meeting. The said appointment shall not render the appointee ineligible to election to any office.

OFFICERS.

C 26. At each Annual Meeting there shall be elected from among the Members and Associates:

A President to hold office for one year.

Two Vice-Presidents, one to hold office for one year and one to hold office for two years. After the first year one Vice-President to be elected annually for a term of two years.

A Treasurer to hold office for one year.

Nine Members or Associates shall be elected to the Council at the first Annual Meeting, three to hold office for one year, three to hold office for two years and three to hold office for three years, and at each subsequent Annual Meeting three Members or Associates shall be elected, each to serve three years.

C 27. The election of officers shall be by ballot, as the By-Laws shall provide.

C 28. The term of all elective officers shall begin on the adjournment of the Annual Meeting of the Society. Officers shall

continue in their respective offices until their successors have been installed.

C 29. A President or Vice-President shall not be eligible for immediate re-election to the same office at the expiration of the term for which he was elected.

C 30. The Council, at its first meeting after the Annual Meeting of the Society, shall appoint a Member or Associate to serve as Secretary of the Society subject to the pleasure of the Council. The Secretary shall receive a salary which shall be fixed by the Council at the time of his appointment.

C 31. The President, Secretary and Treasurer shall perform the duties legally or customarily attaching to their respective offices under the laws of the State of New York, and such other duties as may be required of them by the Council.

C 32. A vacancy in the office of President shall be filled by the Vice-President who is senior by age.

MEETINGS.

C 33. The Society shall hold its Annual Meeting in New York City in the month of December, and such other meetings shall be held at such time and place as the Council may appoint. Twenty-five Members and Associates shall constitute a quorum for the transaction of business.

C 34. Special meetings of the Society may be called at any time at the discretion of the Council or shall be called by the President upon the written request of twenty-five members entitled to vote.

C 35. Any appropriation recommended by the Society at a meeting shall not take effect until it has been approved by the Council.

C 36. Every question which shall come before a meeting of the Society or of the Council or a Committee shall be decided by a majority of the votes cast, unless otherwise provided in this Constitution or the By-Laws, or the Laws of the State of New York. The Council may order the submission of any question to the membership for discussion by letter ballot. Any meeting of the Society at which a quorum is present may order the submission of any question to the membership for discussion by letter ballot.

STANDING COMMITTEES.

C 37. The standing committees of the Society shall be:

Finance Committee. Publication Committee.

Membership Committee.

The members of these Committees shall be appointed by the President from members of the Council who are not officers of the Society.

TRANSACTIONS.

C 38. The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings. Matters relating to politics, religion or purely to trade shall not be discussed at a meeting of the Society nor be included in the transactions.

C 39. The Society shall not approve any engineering or commercial enterprise, nor allow its imprint or name to be used in any commercial work or business. No member shall describe himself in connection with the Society in any advertisement other than as a Member, Associate Member or Junior Member.

AMENDMENTS.

C 40. At Annual Meetings of the Society any Member or Associate may propose in writing for discussion an amendment to this Constitution. Such proposed amendment shall not be voted on at that meeting, but shall be open for discussion and such modification as may be accepted by the proposer. The proposed amendment shall be mailed by the Secretary to each Member and Associate at the time the notice of the next Annual Meeting issues, and shall be voted upon at said meeting.

C 41. Such By-Laws shall be enacted as will conform with this Constitution and the Laws of the State of New York and as are required to conduct the business of the Society.

BY-LAWS.

CANDIDATES FOR MEMBERSHIP.

B 1. A candidate for admission to the Society as a Member or as an Associate must make application on a form approved by the Council, upon which he shall write a statement giving a complete account of his qualifications and engineering experience, and an agreement that he will, if elected, conform to the Constitution, By-Laws and Rules of the Society. He must refer to at least four Members or Associates to whom he is personally known.

B 2. Applications for membership from Refrigerating Engineers who are not residents in the United States or Canada and

who may be so situated as not to be personally known to four Members or Associates of the Society, as required in the foregoing paragraph, may be recommended for ballot by four members of the Council, after sufficient evidence has been secured to show that in their opinion the applicant is worthy of admission to the grade which he seeks.

B 3. A candidate for admission to the Society as a Junior must make application in the same manner as provided for Members or Associates, except that he must refer to not less than three Members or Associates to whom he is personally known.

B 4. The references for each candidate for admission to the Society shall be requested to make a confidential communication to the Membership Committee, setting forth in detail such information, personally known to the referee, as shall enable the Council to arrive at a proper estimate of the eligibility of the candidate for admission to the Society.

ELECTION OF MEMBERS.

B 5. The Secretary shall mail to each member entitled to vote, at least thirty days in advance of any meeting, a ballot stating the names and the respective grades of the candidates for membership in the Society which have been approved by the Council, and the time of the closure of voting. The voter shall prepare his ballot by crossing out the names of candidates rejected by him, and shall enclose said ballot in a sealed blank ballot envelope, which he shall then enclose in a second sealed outer envelope on which he shall, for identification, write his name in ink. The ballot thus prepared and enclosed shall be mailed or delivered unopened to the Tellers of Election. The Secretary shall certify to the competency and the signature of all voters. On the closure of voting, the Tellers of Election shall first open and destroy the outer envelopes, and shall then canvass the ballots, and certify the result to the meeting of the Society.

B 6. The Tellers of Election shall not receive any ballot after the stated time of the closure of voting. A ballot without the endorsement of the voter, written in ink on the envelope, is defective, and shall be rejected by the Tellers of Election.

B 7. The names of those persons elected to membership, with their respective grades, shall be embodied in a written report, signed by the Tellers, and presented to the next meeting of the Society. The President shall then declare them duly elected to membership

in the Society. The Tellers may, through the Secretary, in advance of any meeting, advise each candidate of the result of the canvass of the votes in his case. The names of applicants who are not elected shall neither be announced nor recorded in the Transactions.

B 8. The endorsers of an applicant who has not been elected may, with his consent, present to the Council a written request for a re-submission of his name to ballot. The Council may, in its discretion, by a three-fourths vote of the members present, order the name of the applicant placed on the next ballot for members.

B 9. Each person elected to membership must subscribe to the Constitution, By-Laws and Rules of the Society, and pay the initiation fee before he can receive a certificate of membership in the Society.

ELECTION OF OFFICERS.

B 10. The Secretary shall mail to each member entitled to vote, at least thirty days before the Annual Meeting, the names of the candidates for office proposed for election by the Nominating Committees.

B 11. The names of the candidates proposed by the Nominating Committee or Committees, and the respective offices for which they are candidates, shall be printed in separate lists on the same ballot sheet, each list of candidates to be printed under the names of the members of the particular committee which proposed it.

B 12. The name of any candidate on the ballot may be erased, and the name of any person qualified to hold the office written in its stead. The ballot must be voted and canvassed in the same manner as for the election of members.

B 13. In case of a tie in the vote for any officer, the President, or, in his absence, the Presiding Officer, shall cast the deciding vote.

B 14. A ballot which contains more names on it than there are officers to be elected is thereby defective, and shall be rejected by the Tellers.

FEES AND DUES.

B 15. The initiation fee and annual dues of the first year shall be due and payable on notice of election to membership. Thereafter the annual dues shall be due and payable on the first day of December in each year.

B 16. A member in arrears for one year shall not be entitled to vote until such arrears have been paid. Should the right to vote be questioned, the books of the Society shall be conclusive evidence.

B 17. The Secretary shall present to the Council the name of any Member, Associate or Junior in arrears for more than one year. A person dropped from the rolls for non-payment of dues may, at the discretion of the Council, be restored to the privileges of membership upon payment of all arrears.

FINANCIAL ADMINISTRATION.

B 18. The Council at its first meeting in each fiscal year shall consider the recommendations of the Finance Committee concerning the expenditure necessary for the work of the Society during that year. The apportioning of the work of the Society among the various standing and other Committees shall be on a basis approved by the Council and in harmony with the Constitution and By-Laws. The appropriations approved by the Council, or so much thereof as may be required for the work of the Society, shall be expended by the various Committees of the Society, and all bills against the Society for such expenditure shall be certified by the Committee making the expenditure and shall then be sent to the Finance Committee for audit. Money shall not be paid out by any officer or employee of the Society except upon bills duly audited by the Committee, or by resolution of the Council.

FINANCE COMMITTEE.

B 19. The Finance Committee shall consist of three members of the Council appointed for a term of one year. The Committee shall, under the direction of the Council, have supervision of the financial affairs of the Society, including the books of account.

PROGRAMME COMMITTEE.

B 20. The President shall appoint a Committee from the members of the Council who shall procure professional papers, to pass upon their suitability for presentation, and to suggest topical subjects for discussion at the meetings. The Committee may refer any paper presented to the Society to a person or persons, especially qualified by theoretical knowledge or practical experience, for their suggestions or opinions as to the suitability of the paper for presentation. Papers from non-members shall not be accepted except by unanimous vote of the Committee. The Committee shall arrange the programme of each meeting of the Society, and shall have general charge of the entertainments to be provided for the members and

guests at each meeting. It shall prohibit the distribution or exhibition at the headquarters or at the meeting places of the Society of all advertising circulars, pamphlets or samples of commercial apparatus or machinery. At the end of each fiscal year the Committee shall deliver to the Secretary for presentation to the Council a detailed report of its work.

PUBLICATION COMMITTEE.

B 21. The Publication Committee shall consist of three members of the Council appointed for a term of one year. The Committee shall review all papers and discussions which have been presented at the meetings, and shall decide what papers or discussions, or parts of the same, shall be printed. At the end of each fiscal year the Committee shall deliver to the Secretary for presentation to the Council a detailed report of its work.

MEMBERSHIP COMMITTEE.

B 22. The Membership Committee shall consist of three members of the Council appointed for a term of one year. It shall be the duty of this Committee:

To receive and scrutinize all applications for membership to the Society.

To seek further information as to the qualifications of any applicant whose evidence of eligibility is not clear to the Committee.

To report to each session of the Council the names of all applicants under consideration, together with the action of the Committee on each.

The Committee shall at once destroy all correspondence in relation to each applicant when his name has been placed on the ballot by order of the Council, or upon the withdrawal of the application.

NOMINATING COMMITTEES.

B 23. A Nominating Committee of five Members or Associates shall be appointed by the President within three months after he assumes office. It shall be the duty of this Committee to send to the Secretary on or before October first the names of consenting nominees for the elective offices next falling vacant under the Constitution. Upon the request of any Member or Associate, the Secretary shall furnish to the applicant the names of such nominees.

B 24. A special Nominating Committee, if organized, shall, on

or before October twentieth, present to the Secretary the names of the candidates nominated by it for the elective offices next falling vacant under the Constitution, together with the written consent of each.

TELLERS.

B 25. The Presiding Officer shall, at the first session of the Annual Meeting, appoint three Tellers of Election of Officers, whose duties shall be to canvass the votes cast, and report the result to the meeting. Their term of office shall terminate when their report of the canvass is presented to the meeting.

B 26. The President within one month after assuming office shall appoint three Tellers of Election of Members to serve for one year, whose duties shall be to canvass the votes cast for members during the year, and to certify the same to the President. They shall notify candidates through the Secretary of the result of such election.

B 27. The President shall appoint three Tellers to canvass any letter ballots which shall be ordered by the Council or by the Society.

SECRETARY.

B 28. The Secretary of the Society shall be the Secretary to the Council.

The Secretary shall, under the supervision of the Finance Committee, have charge of the Books of Account of the Society.

He shall make and collect all bills against members or others.

All bills against the Society shall be delivered to the Secretary. He shall immediately enter them in the Books of Account, and shall immediately deposit such funds as he receives to the credit of the Society in a bank to be designated by the Council.

TREASURER.

B 29. The Treasurer shall make payments only on the audit of the Finance Committee, or upon the direction of the Council, by resolution of that body. He shall furnish a bond for the faithful performance of his duties to such amount as the Council may require, such bond to be procured from an incorporated Guarantee Company, at the expense of the Society.

TITLES, EMBLEMS, CERTIFICATES.

B 30. Each Member, Associate and Junior shall, subject to such rules as the Council may establish, be entitled on request to

a certificate of membership, signed by the President and Secretary of the Society. Every such certificate shall remain the property of the Society, and shall be returned to it on demand of the Council.

B 31. Each proxy authorizing a person to vote for an absent member shall be signed by such absent member, with an attesting witness, and be submitted to the Secretary for verification of the member's right to vote at the meeting at which the right is to be exercised.

B 32. The emblem of each grade of membership approved by the Council shall be worn by those only who belong to that grade. The official stationery shall be used only by Officers and Committees of the Society for official business.

B 33. The abbreviations of the titles of the various grades of membership approved by the Society are as follows:

For Members—Mem. Am. Soc. R. E.

For Associates—Assoc. Am. Soc. R. E.

For Juniors—Jun. Am. Soc. R. E.

ORDER OF BUSINESS.

B 34. Roll Call.

Reading of Minutes of Previous Meeting.

Report of Officers—President, Secretary, Treasurer.

Reports of Standing and Special Committees.

Unfinished Business.

Report of Tellers of Elections.

New Business.

Reading of Papers and Discussions.

PARLIAMENTARY RULES.

B 35. In all questions arising at any meeting, involving parliamentary rules not provided for in these By-Laws, "Cushing's Manual" shall be the governing authority.

CONTENTS OF VOLUME I.

			PAGE.
No. 1.		President Starr's Address	37
No. 2.	JOHN E. STARR.	Pipe Line Refrigeration	41
No. 3.	EDGAR PENNEY.	Elements Governing the Selection of the "Plate" System and the "Can" System	55
No. 4.	W. T. ROBINSON.	Cold Storage Requirements for the Refrigeration of Perishable Products	71
No. 5.	G. HAROLD POWELL.	The Transportation of Fruit in Refrigeration	82
No. 6.	WALTER C. REID.	Furs and Fabrics in Cold Storage	95
No. 7.	LOUIS BLOCK.	The Evaporator and Its Use in the Manufacture of Can Ice	102
No. 8.	J. C. GOOSMANN.	The Carbonic Acid Refrigerating Machine.	112
No. 9.	HENRY TORRANCE, JR.	Does a 100-Ton Ammonia Compression Plate Ice-Making Plant or a 100-Ton Absorption Plate Ice-Making Plant Equal in Economy a 50-Ton Compression Machine in Combination with a 50-Ton Absorption Machine, Using the Exhaust of the Compression Machine for Operating the Absorption Machine?	126
No. 10.	W. EVERETT PARSONS.	The Practical Value of Indicating the Ammonia Compressor	137
No. 11.	MARTIN R. CARPENTER.	Requirements of Small Refrigerating Plants of Less Than One Ton Capacity.	157
No. 12.	*Discussion.*	Brine versus Direct Expansion in Plate Ice-Making Plants	164
No. 13.	*Discussion.*	Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?	167
No. 14.	*Discussion.*	Principal Cause of Non-Condensable Gases in Ammonia Machines	169
No. 15.	*Discussion.*	The Best Method of Removing Oil from Hot Ammonia Gas	170
No. 16.	*Discussion.*	Under What Conditions Does it Pay to Use a Cooling Tower?	171
No. 17.	*Discussion.*	Is Ammonia Gas Inflammable?	175
No. 18.	*Discussion.*	Experience in the Use of Boiler Compounds in Can Ice Plants	179

PROCEEDINGS

OF THE

FIRST ANNUAL MEETING

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

New York, N. Y., December 4 and 5, 1905.

The first annual meeting of the Society was held in New York, N. Y., pursuant to the provisions of the Constitution and charter, issued under the laws of the State of New York, on Monday and Tuesday, December 4 and 5, 1905. Four sessions were held, Monday morning, afternoon and evening and Tuesday morning, all being called to order by Mr. John E. Starr, the first President of the Society, in the chambers of The American Society of Mechanical Engineers, No. 12 West Thirty-first street.

FIRST SESSION, MONDAY MORNING, DECEMBER 4.

The opening session of the meeting was called to order shortly after 9:30 A. M., and the following responded to the roll-call of Charter Members:

Behn, Carl.....New York, N. Y.
Berna, George.....Baltimore, Md.
Block, Louis.....New York, N. Y.
Carpenter, M. R, New Brunswick, N. J.
Cary, Albert A.....New York, N. Y.
Cole, Harold W.....New York, N. Y.
Collins, John G.....Chicago, Ill.
Criswell, A. P.....Chicago, Ill.
De Hart, Jr., John S., Newark, N. J.
Flocke, Frank J.....New York, N. Y.
Friedmann, E. N....New York, N. Y.
Gueth, Oswald.....New York, N. Y.
Haven, Harry M.....Boston, Mass.
Jacobus, D. S.....Hoboken, N. J.
Jenks, L. Howard..New York, N. Y.
Louis, J. Shipman...Cincinnati, Ohio
Manns, W. H.....Waynesboro, Pa.
Matthews, F. E....New York, N. Y.
McCarthy, George L., New York, N. Y.
Palmer, C. C.....New York, N. Y.
Parsons, W. Everett, New York, N. Y.
Penney, Edgar.....Newburgh, N. Y.
Reid, Walter C.....New York, N. Y.
Robinson, W. T.....Philadelphia, Pa.
Ross, William H., New York, N. Y.
Rowe, Samuel J....New York, N. Y.
Shipley, Samuel J...New York, N. Y.
Shipley, Thomas.....York, Pa.
Starr, John E.....New York, N. Y.
Torrance, Jr., Henry, New York, N. Y.
Vesterdahl, Karl E., New York, N. Y.
Vogt, Henry.....Louisville, Ky.
Voorhees, Gardner T..St. Louis, Mo.
Whelan, Robert A.....Chicago, Ill.
Williams, L.....Boston, Mass.
Wills, James.....New York, N. Y.

The minutes of the organization meeting were then read and approved. They follow:

MINUTES OF THE ORGANIZATION MEETING OF THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

The organization meeting of The American Society of Refrigerating Engineers was called to order in the chambers of The American Society of Mechanical Engineers, No. 12 West Thirty-first street, New York City, at 10:15 A. M., on Monday, December 5, 1904, by John E. Starr, temporary chairman.

Two sessions were held, one in the morning and the other in the evening.

Mr. Starr was made permanent chairman.

W. H. Ross was appointed secretary of the meeting.

After the chairman had stated the objects of the meeting, which were to receive the report of the committee appointed to draft a Constitution and By-Laws, consisting of L. Howard Jenks, chairman; John E. Starr, W. Everett Parsons, James Wills, Henry Torrance, Jr., E. L. Phillips, vice George Richmond, deceased, and W. H. Ross, named at a meeting held in these rooms on April 2, 1904, and to elect officers for the ensuing year, the minutes of the April meeting were read and accepted.

As no order of business had yet been established, the chairman called on the committee for its report. Mr. Jenks, as chairman of the committee, stated that its report consisted of the Constitution and By-Laws as drafted, which spoke for themselves, and which he respectfully submitted. He further stated that there were a great many meetings held and that the instruments of association of many engineering societies, both in America and Europe, were consulted, that the committee might derive ideas and suggestions from them. He also stated that the Constitution and By-Laws might be a little long, but they were put in that shape with the view to meet the requirements of a society that is expected to grow in size and importance, and they therefore cover a good many points. He further stated that they were submitted in a tentative way to an attorney to see that they complied with the laws.

On motion the Constitution and By-Laws were read by the Secretary.

After considerable discussion the Constitution and By-Laws were accepted by unanimous vote, after the words "in writing" had been inserted after the words "given to a voting member" in paragraph C 8 of the Constitution, under the division of "Membership."

Following the acceptance of the Constitution and By-Laws it was moved that a Nominating Committee of three be appointed by the chairman, to nominate from among those invited by the committee to attend the organization meeting to fill the offices prescribed in the Constitution and By-Laws and to report at the evening session.

The chairman appointed Karl E. Vesterdahl, chairman, Edgar Penney and Henry Torrance, Jr., as the committee.

The meeting adjourned at 11:45 to meet at 9 o'clock in the evening.

The evening session began at 9:30, with Chairman Starr presiding.

The first business to come before this session was the report of the Nominating Committee, which was as follows:

President—John E. Starr.

Vice-Presidents—P. De C. Ball and H. B. Roelker.

Treasurer—Walter C. Reid.

Directors—W. Everett Parsons, Henry Torrance, Jr., E. L. Phillips, D. S. Jacobus, L. Howard Jenks, Louis Block, Edgar Penney, W. T. Robinson and Thomas Shipley.

W. T. Robinson moved that that part of the Constitution and By-Laws referring to the time, election and method of election of officers be suspended in order that those selected by the Nominating Committee might be installed, and that the Secretary cast a ballot for the entire list of names presented as officers of the Society. The motion was carried.

The Secretary was instructed to furnish a copy of the proceedings of the meeting to technical publications that might desire them.

The Council was requested and given authority to employ an attorney to have the Society incorporated under the laws of the State of New York, as required in the Constitution.

It was then moved that the Treasurer be empowered to pay all bills incurred by the Organization Committee as approved by the Council.

The business of the meeting having been completed, a discussion was had on the standard unit of refrigeration, in which nearly all present took part.

On motion of Gardner T. Voorhees the President was instructed to appoint a committee of five to investigate and report a proposed standard rating for refrigerating apparatus, to be voted on at the next annual meeting of the Society.

The meeting adjourned at 11 P. M.

(Signed) WILLIAM H. ROSS, *Secretary.*

The report of the Tellers of Election of Membership was next heard. It was as follows:

REPORT OF TELLERS OF ELECTION OF MEMBERSHIP.

NEW YORK, November 15, 1905.

MR. JOHN E. STARR, PRESIDENT,
The American Society of Refrigerating Engineers,
No. 258 Broadway, New York City.

Dear Sir:

The undersigned met as Tellers of Election of Members for canvassing the vote for Membership to The American Society of Refrigerating Engineers on November 15, in accordance with Section C 15 of the Constitution and Sections B 5, B 6 and B 7 of the By-Laws, and beg to submit herewith the following report:

Forty-five (45) ballots were received, one (1) of which was void.

The following were elected to membership in the various grades as indicated:

FOR MEMBERS.

Henning N. Borgstedt,
Henry J. Botchford,
Benjamin F. Daly,
Samuel R. Frantz,
William Hargreaves,
Arthur Meltzer,
O. J. Morris,
William Nottberg,
E. H. Oderman,
Edward William Schadek,
Robert Lee Shipman,
Edmond James Smith,
Edgar Wakelin Thompson,
Arthur R. T. Woods,
Willard J. Woodcock.

FOR ASSOCIATES.

Philip Ray Allen,
John C. Atwood,
Charles Herbert Brownell,
Edwin Burhorn,
Cecil H. Grundy Croll,
James Ely,
Edward Everett,
R. B. Fentress,
J. Graham Glover,
David E. Haire,
Benjamin Franklin Hart, Jr.,
F. H. Herst,
Walter L. Hill,
Homer McDaniel,
John G. McKinney,
Stephen E. McPartlin,
Emerich J. Markel,
Lewis Charles Marshall,
William Fellows Morgan,
Martin J. O'Conner,
James Edwin Quigley,
Albert James Redway,
James P. Reilly,
Henry Francis Salkeld,
Horace Prevost Serrill,
John Montgomery Smart,
Henry W. Tinker,
L. M. Tough,
Charles Lynd Turner,
Ralph D. Van Valkenburgh,
Louis Werliin.

FOR JUNIORS.

Alvin Hayes Baer,
Van Rensselaer Hoff Greene,
Rudolph W. Wittemann.

Respectfully submitted,

(Signed) ELLIS L. PHILLIPS, KARL WEGEMANN, F. H. WHITE, *Tellers of Election of Members.*

After the President had declared the successful applicants for membership duly elected to their respective grades, the Secretary called the roll of the new members and the following responded:

Atwood, John C., St. Louis, Mo.
Borgstedt, Henning N., Boston, Mass.
Botchford, Henry J., Boston, Mass.
Brownell, C. H., Washington Court House, Ohio.
Burhorn, Edwin, New York, N. Y.
Daly, Benjamin F., New York, N. Y.
Greene, Van Rensselaer H., New York, N. Y.
Haire, David E., Philadelphia, Pa.
Herst, Franklin H., Philadelphia, Pa.
Ely, James, New York, N. Y.
Morris, O. J., Dallas, Tex.
O'Conner, Martin J., Brooklyn, N. Y.
Quigley, J. E., Pittsburgh, Pa.
Shipman, R. L., Ithaca, N. Y.
Werliin, Louis, Philadelphia, Pa.
Wittemann, R. W., Brooklyn, N. Y.

The report of the Council was now called for, and, after being read by the Secretary, was unanimously accepted. It follows:

REPORT OF THE COUNCIL OF THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS FOR THE FISCAL YEAR ENDING DECEMBER 1, 1905.

The Council has held three executive sessions during the year, and respectfully presents herewith a report of the business transacted, pursuant to the provisions of the Constitution and By-Laws.

The amount of real and personal property owned by the Society, the

property acquired during the year, the amount applied, appropriated or expended, and the purposes and objects for which such expenditures have been made, are contained in the report of the Finance Committee, which follows:

REPORT OF THE FINANCE COMMITTEE.

Amount received—	Charter Members.	New Members.	
Initiation Fees	$320	$155	= $475.00
Dues	680	255	= 935.00
Emblems			82.10
Banquet			3.00
			$1,495.10

Disbursements—	
Luncheon organization meeting	$42.00
Emblems	70.45
Furniture	18.62
Membership certificates	65.50
Premium on Treasurer's bond	5.00
Printing	221.65
Rent of A. S. M. E. rooms for organizing meeting	55.00
Salaries	250.00
Stenographer for organization meeting	40.00
Petty cash	124.71
	$892.93
Balance on hand	$602.17

It will be noted that there remains a balance of $107.07 from the amounts received in the form of initiation fees and optional dues from the Charter Members, after the many expenditures incidental to the organization of the Society have been liquidated.

The Council had 1,000 copies of the "Year Book" printed. About 200 remain to be distributed.

The following have been admitted to membership in the Society in the three grades during the year:

MEMBERS.

Henning N. Borgstedt, Boston, Mass.
Henry J. Botchford, Boston, Mass.
Benjamin F. Daly, New York, N. Y.
Samuel R. Frantz, Waynesboro, Pa.
William Hargreaves, Atlanta, Ga.
Arthur Meltzer, San Francisco, Cal.
O. J. Morris, Dallas, Tex.
William Nottberg, Kansas City, Mo.
E. H. Oderman, Waynesboro, Pa.
Edward Schadek, St. Louis, Mo.
Robert Lee Shipman, Ithaca, N. Y.
Edmond Smith, Memphis, Tenn.
Edgar Thompson, Bombay, India.
Willard J. Woodcock, Brooklyn, N. Y.
Arthur R. T. Woods, Spring Grove, Town Roy, West Derby, Liverpool, England.

ASSOCIATES.

Philip Ray Allen, East Walpole, Mass.
John C. Atwood, St. Louis, Mo.
Charles Herbert Brownell, Washington Court House, Ohio.
Edwin Burhorn, New York, N. Y.
Cecil H. G. Croll, Wellington, New Zealand.
James Ely, New York, N. Y.
Edward Everett, New York, N. Y.
R. B. Fentress, Norfolk, Va.
J. Graham Glover, Brooklyn, N. Y.
David E. Haire, Philadelphia, Pa.
Benjamin F. Hart, Jr., New York, N. Y.
F. H. Herst, Philadelphia, Pa.
Walter L. Hill, Boston, Mass.
Homer McDaniel, Cleveland, Ohio.
John G. McKinney, Los Angeles, Cal.
Stephen E. McPartlin, Chicago, Ill.
Emerich J. Markel, Hartford, Conn.
Lewis C. Marshall, New York, N. Y.
William Fellows Morgan, New York, N. Y.
Martin J. O'Conner, Brooklyn, N. Y.
James E. Quigley, Pittsburgh, Pa.
Albert J. Redway, Cincinnati, Ohio.
James P. Reilly, New York, N. Y.
Henry F. Salkeld, New York, N. Y.
Horace P. Serrill, Philadelphia, Pa.
John Montgomery Smart, New York, N. Y.
Henry W. Tinker, Boston, Mass.
L. M. Tough, Baltimore, Md.
Charles L. Turner, Philadelphia, Pa.
Ralph D. Van Valkenburgh, Hudson, N. Y.
Louis Werliin, Philadelphia, Pa.

JUNIORS.

Alvin Hayes Baer, Waynesboro, Pa.
Van Rensselaer Hoff Greene, New York, N. Y.
Rudolph W. Wittemann, Brooklyn, N. Y.

Twelve applications for membership have been received since the issuance of the ballot for membership. These will receive the attention of the Council at its first session after the annual meeting.

The Membership Committee held several sessions and carefully investigated the qualifications of each applicant for membership, and the result of the canvass of ballots shows how well it did its work.

While the Society is only celebrating its first anniversary, the Council has to report in the demise of Mr. Rockwell King the loss of one of its most valued members. Mr. King died at his home in Chicago, Ill., on July 27, of blood poisoning. It is hoped that some member shall offer suitable resolutions at this meeting, and a copy be ordered sent to his bereaved family.

William H. Ross was appointed Secretary of the Society, subject to the pleasure of the Council, at its first meeting at a salary of $25 a month, out of which all expenses of that office are to be paid.

The following committee appointments were also made at the first meeting of the Council:

MEMBERSHIP COMMITTEE.

W. T. Robinson, Thomas Shipley and Ellis L. Phillips.

FINANCE COMMITTEE.

Edgar Penney, Louis Block and L. Howard Jenks.

PUBLICATION COMMITTEE.

D. S. Jacobus, W. Everett Parsons and Henry Torrance, Jr.

PROGRAMME COMMITTEE.

L. Howard Jenks, D. S. Jacobus, W. Everett Parsons and Henry Torrance, Jr.

Ellis L. Phillips, Karl Wegemann and Frank H. White were named as Tellers of Election of Membership. These tellers met on November 15 and canvassed the ballots.

The Society was duly incorporated as a membership corporation under the laws of the State of New York on August 30. This matter received the attention of the Finance Committee. It is not out of place to mention in connection with this subject that many and valuable services, without fee, were rendered and advice given by our fellow member, Attorney John C. Wait, in the preparation of the instrument of incorporation, and the Council takes this opportune occasion to thank him for his many courtesies.

The membership certificates of the charter members bear the date of September 12, 1905, to distinguish them from the certificates of future issue. The design and wording of these certificates were the result of many deliberations of the Publication Committee. The emblem is also the product of this committee.

In order to distinguish the difference between the emblems of the various grades of membership it has been established that the background of the monogram in the Member's emblem be dark blue; that in the Associate white, and in the Junior light blue or turquoise. It has also been established that the emblems be five-eighths of an inch in diameter.

The Council has approved that the seal of the Society be the same as the Member's emblem as far as practicable, after conforming with the requirements of the laws of the State of New York.

The Nominating Committee, consisting of Carl Behn, chairman; Fred B. Church, Karl Wegemann, Samuel J. Shipley and Edward N. Friedmann, met on August 30, and selected members to fill the offices next falling vacant under the Constitution, and made its report to the President on September 15.

The effectiveness of the work of the Programme Committee will be made fully apparent at this meeting. It has been the result of sessions of long duration and much thought. In fact the most arduous work has fallen to the lot of the gentlemen comprising this committee.

The Finance Committee, under the direction of the Council, has formally made application for space for the needs of this Society in the United Engineering Society Building, the gift of Mr. Andrew Carnegie, now in course of construction, and has received the following communication from Mr. F. R. Hutton, Secretary of the Engineering Building Committee, under date of July 19:

THE ENGINEERING BUILDING COMMITTEE.

OFFICE OF SECRETARY AND TREASURER,
No. 12 West Thirty-first Street,
NEW YORK, July 19, 1905.

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.

Dear Sirs:

I have your communication of July 1, as Secretary of the Trustees of the United Engineering Society, asking that your organization may be considered in the allotment of space in the new engineering building.

Your application is one of the earliest received, and will be carefully considered by the Trustees at an early date.

It is too soon at this time for the committee to undertake detailed consideration of assignment, but in the early autumn these matters will come up.

(Signed) F. R. HUTTON, *Secretary.*

The Council understands that the committee has not considered the allotment of space up to this time.

It was hoped that a spring meeting could be held, but matters looking to a complete organization of the Society could not be completed in time and it was abandoned.

Six of the charter members have yet to remit their dues, and it is hoped that they will favor the Council with the amount within the next few days, or the Council will have to follow the course prescribed in the Constitution and By-Laws in reference to delinquent members.

The Council is indebted to Mr. Francis H. Hoadley, Assistant to the Secretary of The American Society of Mechanical Engineers, for many kindnesses extended.

It is hoped that the finances of the Society will be in such shape by the end of next year as to warrant the Council issuing printed copies of the papers to be presented in advance of the Annual Meeting, in order that they may be properly discussed. Respectfully submitted,

(Signed) JOHN E. STARR, *President.*

W. T. Robinson.—If it is in order, I would move that the suggestion of the Council be adopted, that a committee be appointed to prepare resolutions concerning the death of Rockwell King.

Motion carried.

The President.—I will appoint W. T. Robinson and C. H. Brownell as the committee.

Any other unfinished business, gentlemen?

Gardner T. Voorhees.—I would like to ask, under the head of unfinished business, who was appointed on the committee to report regarding establishing the Standard Unit Ton for refrigerating machines?

The President.—I will say for the information of the members that, under advice of the Council, it was thought well for the present to defer the appointment of this committee; not meaning in the least that the committee shall not be appointed, but simply to defer the time until what seemed to the Council to be a somewhat more favorable opportunity. The matter, as you all know, has been taken up by The American Society of Mechanical Engineers and their labors are only partially completed. It was thought better, therefore, without disregarding the motion and the order of the Society, to defer the appointment of that committee until a little later.

New business is now in order.

J. Shipman Louis.—In accordance with paragraph C 40, under the division of "Amendments" of the Constitution, I beg to propose an amendment to paragraph C 33, under the division of "Meetings," of the Constitution, for discussion at this meeting and for final action at the next Annual Meeting as the Constitution provides.

Where paragraph C 33 of the Constitution reads "The Society shall hold its Annual Meeting in New York City in the month of December," I would have it read "The Society shall hold its Annual Meeting in New York City on the Monday preceding the first Tuesday in December," in order that it may be in accord with our charter, as the laws of the State of New York require that the date of the Annual Meeting of a corporation be specifically given in its articles of association; and I also propose an amendment to paragraph B 34, under the division "Order of Business," of the By-Laws. This paragraph now reads as follows:

B 34. *a.* Roll Call.
b. Reading of minutes of previous meeting.
c. Report of Officers—President, Secretary, Treasurer.
d. Reports of standing and special committees.
e. Unfinished business.
f. Report of tellers of election.
g. New business.
h. Reading of papers and discussions.

I propose that it read:

B 34. Roll Call.
Reading of minutes of previous meeting.
Report of the Tellers of Election of Membership.
Report of the Council.
Unfinished business.
New business.
Report of the Tellers of Election of Officers.
Reading of papers and discussions.

Under the latter proposed amendment the Annual Meetings will be conducted in greater harmony with the provisions of the Constitution and By-Laws covering these points.

L. Howard Jenks.—It seems very clear that the motion should prevail to bring our practice in conformity with the Constitution. It is a matter that was overlooked in drafting the "Order of Busi-

ness." The report of the Council embodies the reports of the officers and committees.

Gardner T. Voorhees.—Would it not be well to consider whether or not that date would conflict with the meetings of The American Society of Mechanical Engineers?

The President.—I assume that the Council had a hand in preparing these resolutions and went into that matter. I am not sure as to this point; possibly some of the Council could enlighten us.

The Secretary.—Mr. President, our charter states that the Annual Meeting shall be held on the Monday before the first Tuesday in December, and when the Council established that date it took into consideration that The American Society of Mechanical Engineers held its first business meeting on the first Tuesday of that month, and it desired to get the two dates as near together as possible, so that anyone, a member of both societies, coming to the city could attend both meetings without loss of time.

Gardner T. Voorhees.—How is it possible to amend the By-Laws of this association, supposing at any time it were desired to do so?

The President.—The provision for this seems to be clearly set forth in paragraph C 40 on page 20 of the "Year Book." While it is true that in the body of this clause it mentions amendments to the Constitution, it would appear that as the By-Laws are subservient to the Constitution and really a part of the Constitution, in a way, I should think that amendments to the By-Laws could be made in the same way as provided in paragraph C 40. I would like to hear Mr. Robinson say something on this point.

W. T. Robinson.—I think the Chair's ruling is correct. As I read it, the By-Laws are really a part of the Constitution, and I should say that the same yearly notice would have to be given and acted on at the next Annual Meeting.

The next order of business was the report of the Tellers of Election of Officers. It was as follows:

REPORT OF TELLERS OF ELECTION OF OFFICERS.

NEW YORK, December 4, 1905.

MR. JOHN E. STARR, PRESIDENT.

We, the undersigned Tellers of Election of Officers for The American Society of Refrigerating Engineers, certify that we met and canvassed the

ballots for election of officers for the ensuing year, and find forty-eight ballots cast for the following:

W. Everett Parsons, President.
John E. Starr, Vice-President.
Walter C. Reid, Treasurer.
Louis Block,
Edgar Penney,
H. B. Roelker, } Directors.

Four ballots void. No other ballots cast.

We certify to the election of each of the above named officers.

(Signed) C. H. BROWNELL,
J. S. LOUIS,
W. H. MANNS, } *Tellers of Election of Officers.*

The President.—It remains only for the Chair to declare these officers duly elected, and I believe that by the Constitution their terms of office commence with the adjournment of this Annual Meeting. I will be very glad, however, if the President-elect, Mr. Parsons, would join me in the balance of the meeting, and I will appoint Mr. Penney and Mr. Berna as a committee to escort our President-elect to the Chair.

President-elect Parsons (after being escorted to a seat beside the President).—I wish only to say that I appreciate the honor very much, and I will do my best to serve the Society.

The address of the President was now had. It appears in the Proceedings as one of the papers of the meeting.

Following the address of the President, he read a paper on "'Pipe Line Refrigeration."

The participants in the debate on President Starr's paper were Gardner T. Voorhees, W. Everett Parsons, Louis Block, R. L. Shipman, V. R. H. Greene, Edgar Penney, Henry Vogt, W. T. Robinson, Harry M. Haven and L. Williams.

The session adjourned at this point and all retired to the supper room in the basement, where the Programme Committee had lunch served.

SECOND SESSION, MONDAY AFTERNOON, DECEMBER 4.

The meeting was called to order shortly after 1 P. M. The following four papers were presented at this session:

"Elements Governing the Selection of the 'Plate' System and the 'Can' System," by Edgar Penney; "Cold Storage Requirements for the Refrigeration of Perishable Food Products," by W. T. Robinson; "The Transportation of Fruits in Refrigeration," by G. Harold Powell; "Furs and Fabrics in Cold Storage," by Walter C. Reid.

After Mr. Robinson had finished reading his paper he stated that he desired to move the following resolution, but before doing so he would like to hear from G. Harold Powell, of the United States Department of Agriculture, who was present, if he thought it covered the ground:

WHEREAS, The work of the Agricultural Department in its investigations and reports on the preservation of fruits and food products is giving the producers and consumers thereof valuable information; therefore be it

Resolved, That The American Society of Refrigerating Engineers, in convention assembled, recommends that Congress appropriate a sufficient amount to enable the Agricultural Department to equip and maintain a cold storage plant for making such investigations as may be recommended by the Secretary of the United States Department of Agriculture.

Mr. Powell approved of the resolution and further said:

"I want to say that I am very much pleased to hear of this resolution. The Department of Agriculture, as you possibly know, has been carrying on investigations in the last four or five years in various lines of cold storage.

"We have always been restricted in our work by the limitations of commercial warehouses. We have had every facility offered us by the owners of warehouses, but few houses are arranged so that a scientific study of technical warehousing problems can be made. The questions of humidity and of ventilation are of great importance, but the Agricultural Department has not the facilities for studying them. I think that a resolution of that kind would receive a hearty response from the Secretary of Agriculture, who is interested in every line that touches the American farmer. The Secretary is always glad to co-operate with technical organizations that bear directly or indirectly upon the agriculture of this country. So I am certain that these resolutions would be met with a hearty response from the Secretary."

Mr. Robinson then offered his resolution and it was unanimously accepted, and a copy was ordered sent to the Secretary of the Agricultural Department.

On motion, duly made and seconded, the unanimous thanks of the Society were extended to Mr. Powell for his very interesting paper.

The following took part in the discussion on the four papers read at this session:

On Mr. Penney's paper—Thomas Shipley, Louis Block, W. T. Robinson, A. P. Criswell, John C. Sparks, Gardner T. Voorhees, Henry Vogt, S. J. Rowe, George Berna, Harry M. Haven, W. Everett Parsons and John N. Briggs.

On Mr. Robinson's paper—Henry Vogt, Louis Block, Harry M. Haven and the President.

On Mr. Powell's paper—R. L. Shipman, W. T. Robinson, Louis Block, Harry M. Haven, L. Williams and the President.

On Mr. Reid's paper—Henry Vogt and the President.

THIRD SESSION, MONDAY EVENING, DECEMBER 4.

The session was called to order at 8 P. M. The papers read at this session were as follows:

"The Evaporator and Its Use in the Manufacture of Can Ice," by Louis Block; "Does a 100-ton Ammonia Compression Plate Ice Making Plant or a 100-ton Absorption Plate Ice Making Plant Equal in Economy a 50-ton Compression Machine in Combination with a 50-ton Absorption Machine, Using the Exhaust of the Compression Machine for Operating the Absorption Machine?" by Henry Torrance, Jr.; "The Carbonic Acid Refrigerating Machine," by J. C. Goosmann.

The participants in the debate were:

On Mr. Block's paper—Thomas Shipley, Edgar Penney, Albert A. Cary, L. Howard Jenks, R. L. Shipman and the President.

On Mr. Torrance's paper—A. P. Criswell, R. L. Shipman, Gardner T. Voorhees, Edgar Penney, D. S. Jacobus, J. Shipman Louis, Thomas Shipley, S. J. Rowe and the President.

No discussion was had on Mr. Goosmann's paper, as he was unable to be present to read it and participate in the debate. The paper was read by Oswald Gueth.

FOURTH SESSION, TUESDAY MORNING, DECEMBER 5.

The final session of the meeting was called to order shortly after 9 A. M. The following papers were presented:

"The Practical Value of Indicating the Ammonia Compressor," by W. Everett Parsons; "Requirements of Small Refrigerating Plants of Less Than One Ton Capacity," by Martin R. Carpenter.

The following topical discussions also received the attention of this session:

"Brine versus Direct Expansion in Plate Ice Making Plants," "Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?" "Principal Cause of Non-Condensable Gases in Ammonia Machines," "Best Method of Removing Oil from Hot Ammonia Gas," "Under What Conditions Does It Pay to Use a Cooling Tower?" "Is NH_3 Inflammable?" and "Experience in the Use of Boiler Compounds in Can Ice Plants."

The participants in the debate on the two papers were as follows:

On Mr. Parsons' paper—Thomas Shipley, Gardner T. Voorhees, R. L. Shipman, George Berna and Harry M. Haven.

On Mr. Carpenter's paper—C. C. Palmer and E. N. Friedmann.

The participants in the debate on the topical discussions were Thomas Shipley, David E. Haire, Gardner T. Voorhees, George Berna, Harry M. Haven, S. J. Rowe, A. P. Criswell, E. N. Friedmann, John C. Sparks, F. E. Matthews, O. J. Morris, Albert A. Cary, Edwin Burhorn, R. L. Shipman, D. S. Jacobus, W. Everett Parsons and the President.

In the course of the discussion on Mr. Parsons' paper Thomas Shipley, on behalf of the York Manufacturing Company, of York, Pa., extended an invitation to the Society to send a committee to visit its test plant at York, Pa., to establish data on mechanical refrigeration. Mr. Shipley also kindly offered to furnish the necessary men to operate the test plant while any tests the committee might care to make were in progress.

A motion prevailed tendering the thanks of the Society to the York Manufacturing Company and its general manager, Thomas Shipley, for the kind invitation to use the experimental plant.

The President announced that, owing to a death in the family of John C. Wait, he was prevented from attending and reading his paper on "Engineers' Specifications versus Contractors' Warranty," and further stated that he felt it was a disappointment to all and that the sympathy of each member went out to Mr. Wait in his bereavement.

Announcement was made that the papers read at the meeting, as well as the discussions had thereon, would be printed in the two trade journals devoted to mechanical refrigeration—*Cold Storage and Ice Trade Journal* and *Ice and Refrigeration.*

The report of the committee appointed at the first session of the meeting to draft resolutions on the death of Rockwell King reported as follows, which was unanimously approved:

WHEREAS, In the death of Mr. Rockwell King The American Society of Refrigerating Engineers has lost a Charter Member who, had he lived, would have been of much service to the Society in the work it is doing; therefore be it

Resolved, That this Society, at its first Annual Meeting held in New York, December 5, 1905, wishes to express its sincere sympathy with the family of Mr. King, and feels that it has met with an irreparable loss in not having his wise counsel and mature judgment to assist the Society at this time.

Resolved, That this resolution be spread upon the minutes and that a copy be sent to the family of Mr. King.

(Signed) W. T. ROBINSON,
C. H. BROWNELL.

A vote of thanks was extended to The American Society of Mechanical Engineers for the use of its premises and the many other courtesies shown.

A unanimous vote of thanks was extended to the President for the uniform courtesy and great capacity with which he discharged the duties of his office.

The meeting then adjourned.

MEMBERS AND GUESTS ATTENDING MEETING.

Affleck, W. B., Milwaukee, Wis.
Atwood, John C., St. Louis, Mo.
Behn, Carl, New York, N. Y.
Berna, George, York, Pa.
Block, Louis, New York, N. Y.
Borgstedt, H., Boston, Mass.
Botchford, H. J., Boston, Mass.
Briggs, J. N., Coeymans, N. Y.
Brownell, C. H., Washington Court House, Ohio.
Burhorn, E., New York, N. Y.
Carpenter, M. R., New Brunswick, N. J.
Cary, Albert A., New York, N. Y.
Cole, Harold W., New York, N. Y.
Collins, John Glenn, Chicago, Ill.
Criswell, A. P., New York, N. Y.
Daly, Benjamin F., New York, N. Y.
Dannenbaum, H., Philadelphia, Pa.
De Hart, John S., Jr., Newark, N. J.
Ely, James, New York, N. Y.
Farish, J. B., New York, N. Y.
Flinn, E. A., New York, N. Y.
Flocke, F. J., New York, N. Y.
Friedmann, E. N., New York, N. Y.
Gould, O. M., Montreal, Canada.
Graham, Joseph, New York, N. Y.
Greene, George V. K., New York, N. Y.
Greene, Van Rensselaer H., New York, N. Y.
Gueth, Oswald, New York, N. Y.
Haire, David E., Philadelphia, Pa.
Hart, Joseph H., Philadelphia, Pa.
Haven, H. M., Boston, Mass.
Herst, Franklin H., Philadelphia, Pa.
Higgins, E. E., New York, N. Y.
Inglis, W. O., New York, N. Y.
Jenks, L. Howard, New York, N. Y.
Jacobus, D. S., Hoboken, N. J.
Louis, J. S., Cincinnati, Ohio.
McCarthy, George L., New York, N. Y.
Manns, W. H., Waynesboro, Pa.
Matthews, F. E., New York, N. Y.
Morris, O. J., Dallas, Tex.
Nichols, C. K., New York, N. Y.
O'Conner, M. J., Brooklyn, N. Y.
Palmer, C. C., New York, N. Y.
Palmer, G. H., New York, N. Y.
Parsons, W. Everett, New York, N. Y.
Penney, Edgar, Newburgh, N. Y.
Phillips, R., New York, N. Y.
Powell, G. Harold, Washington, D. C.
Quigley, J. E., Pittsburgh, Pa.
Reid, Walter C., New York, N. Y.
Robinson, W. T., Philadelphia, Pa.
Rooksby, Edwin J., Philadelphia, Pa.
Ross, William H., New York, N. Y.
Rowe, S. J., New York, N. Y.
Schmidt, F. E., New York, N. Y.
Shipley, S. J., New York, N. Y.
Shipley, Thomas, York, Pa.
Shipman, R. L., Ithaca, N. Y.
Sparks, John C., New York, N. Y.
Starr, John E., New York, N. Y.
Stone, Junius H., New York, N. Y.
Torrance, Jr., Henry, New York, N. Y.
Vesterdahl, Karl, New York, N. Y.
Vogt, Henry, Louisville, Ky.

MEMBERS AND GUESTS ATTENDING MEETING.—*Continued.*

Voorhees, Gardner T., Boston, Mass.
Wallace, Herbert, New York, N. Y.
Warner, Irving, Wilmington, Del.
Werliin, Louis, Philadelphia, Pa.
Whelan, R. A., Chicago, Ill.
Williams, Llewellyn, Boston, Mass.
Wills, James, New York, N. Y.
Wittemann, R. W., New York, N. Y.

THE BANQUET.

The banquet was held in the College Room of The Arena, Nos. 39-41 West Thirty-first street, on Tuesday evening, December 5, at 7:30. Ex-President John E. Starr acted as toastmaster. Addresses were made by President W. Everett Parsons, ex-President Starr, Dr. J. H. Senner, John C. Sparks, J. N. Briggs, O. J. Morris, John A. Sleicher, O. M. Gould, John C. Atwood.

The following attended the banquet:

Atwood, J. C., St. Louis, Mo.
Bates, Guy, New York, N. Y.
Berna, George, Ithaca, N. Y.
Block, Louis, New York, N. Y.
Borgstedt, H., Boston, Mass.
Briggs, J. N., Coeymans, N. Y.
Brownell, C. H., Washington Court House, Ohio.
Burhorn, E., New York, N. Y.
Carpenter, M. R., New Brunswick, N. J.
Cary, Albert A., New York, N. Y.
Collins, John Glenn, Chicago, Ill.
Criswell, A. P., Chicago, Ill.
Dannenbaum, H., Philadelphia, Pa.
Flocke, F. J., New York, N. Y.
Gould, O. M., Montreal, Canada.
Greene, George V. K., New York, N. Y.
Greene, Van Rensselaer H., New York, N. Y.
Haire, David E., Philadelphia, Pa.
Hamilton, E. M., New York, N. Y.
Herst, Franklin H., Philadelphia, Pa.
Hewitt, R., New York, N. Y.
Jenks, L. H., New York, N. Y.
Lee, Walter, Philadelphia, Pa.
Livezey, John R., Philadelphia, Pa.
Loucks, L. V., Philadelphia, Pa.
Louis, J. S., Cincinnati, Ohio.
Lukens, John M., Philadelphia, Pa.
McCarthy, G. L., New York, N. Y.
Morris, O. J., Dallas, Tex.
Parsons, W. Everett, New York, N. Y.
Penney, Edgar, Newburgh, N. Y.
Philipson-Stow, H. M., New York, N. Y.
Quigley, J. E., Pittsburgh, Pa.
Rooksby, Edwin J., Philadelphia, Pa.
Ross, William H., New York, N. Y.
Rowe, S. J., New York, N. Y.
Senner, Dr. J. H., New York, N. Y.
Shipley, Thomas, York, Pa.
Shipman, R. L., Ithaca, N. Y.
Sleicher, John A., New York, N. Y.
Smart, J. M., New York, N. Y.
Sparks, John C., New York, N. Y.
Starr, John E., New York, N. Y.
Stone, J. H., New York, N. Y.
Torrance, Henry, Jr., New York, N. Y.
Vesterdahl, Karl, New York, N. Y.
Vogt, Henry, Louisville, Ky.
Voorhees, Gardner T., Boston, Mass.
Warner, Irving, Wilmington, Del.
Werliin, L., Philadelphia, Pa.
Whelan, R. A., Chicago, Ill.
Wills, James, New York, N. Y.
Woodcock, W. J., Brooklyn, N. Y.

PAPERS

OF THE

FIRST ANNUAL MEETING

OF

THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

No. 1.

PRESIDENT STARR'S ADDRESS.

GENTLEMEN OF THE AMERICAN SOCIETY OF REFRIGERATING ENGINEERS:

It has fallen to my lot to have the honor of making the first of doubtless a continuous series of annual addresses before an organization which I firmly believe is destined to be a power and an honorable and important influence in a field of applied science that is widening beyond bounds that were only dreamed of two decades ago.

I am not unmindful of the significance, I might almost say the solemnity, of this beginning, for I am fully impressed with the importance of the work already laid out for us and it needs not the eye of a prophet to picture the magnitude of coming events that have cast their shadow before. We have started on a mission similar to that which other great societies in the engineering world are so ably accomplishing, and considering that our particular scope of operation touches on almost every department of human interest, our aims, if attained at all, must be reached by manful, honest effort. The Grail of the engineer must be first and last—the Truth.

To define our field in a word, I may say that we claim as our own all that relates to the production of temperatures, below the ordinary, for useful purposes.

If this be a correct definition, the record of what has been accomplished and what remains to be achieved discloses a sphere of operation worthy of the highest effort.

The commercial genesis of our art had to do almost entirely with the production of ice. I need not present to you, who are so well acquainted with its history, an array of statistics to show how this branch alone has grown to be one of the greatest industries in this country—and the end is not yet.

The immediately following developments were in the line of producing low temperatures for the preservation, transportation and marketing of food products, rendering feasible gigantic operations that were before impossible.

Take a single division of this department—I allude to dairy products of milk, butter, cheese and eggs—and compare it with other industries. Cast up into one sum the total value of our iron

trade, our textile fabrics, our lumber and our cotton, add to this all subsidiary manufactures, and the figures will fall below the volume reached by the four items first mentioned; and yet these products in their production, preservation and distribution, could not be handled as they are to-day without refrigeration.

Our enormous meat handling and packing industry is absolutely dependent on the efficiency of our work.

Not alone, however, does the manufacture of ice and the preservation of food call for our best efforts; for while agriculture in its various departments leans heavily on our shoulders to help through the heat of the day, other extensive interests are as close to us.

Bacchus and Gambrinus rely on us to keep them on their throne.

Metallurgy, the dean of the arts, has called to us for a helping hand.

The Oil King demands our best efforts.

The great textile industries in cotton, silk and the like, with their increasingly severe requirements as to conditions of temperature and moisture, are seeking aid and comfort at our hands.

My Lady Nicotine is wooing us, pleading for help to preserve her graces and the perfume and texture of her soothing leaf.

Photography demands great deeds of us.

The gentle art of perfume production is helpless without us.

Chemical industries are demanding more from us day by day.

Our good brothers, the civil engineers, are calling on us to help sink their shafts and build their tunnels.

Our mining friends look to us to provide a cool place in the Gehenna of their lower levels to recuperate their heat-burdened workmen, and enable them to take out precious ore otherwise not reachable.

Therapy has already made valuable use of our efforts.

Sweltering humanity asks us to render more pleasant its places of meeting, and should we desire to indulge our altruistic tendencies, what greater and nobler field in this direction can be offered than the effective amelioration of conditions in the summer-heated, fever-stricken hospital wards, with the possibilities of comforting the sick and the saving of human life?

I have mentioned these matters, gentlemen, not as a boast of our importance, but as an indication of the gravity of our task.

Mr. Hutton, the secretary of The American Society of Mechanical Engineers, who has been our kind mentor during our formative

period, and to whom we are much indebted for the benefit of his experience and advice, has said to us:

"The Association has a weight in any utterance which is many times greater than those of any individual. The public recognizes that such utterance was made in an arena where, if it could have been intelligently questioned or differed from, it would have undergone that ordeal then and there."

We have undertaken the responsibility of speaking with authority, of finding the truth, and proclaiming it, and a critical world will hold us to our task or pass us by as unworthy.

The broadness and at the same time the clear definition of our field is in itself a sufficient reason for a proper recognition. It rests with ourselves to keep it a representative body—one that shall be respected wherever the name of science is known. It rests with ourselves to make it an organization of which it will be considered an honor to be a member, and to be so careful of our membership that some share of the mantle of whatever authority we may achieve as a body shall be worthily cast over the individual.

In taking up our work a certain sense of perspective is necessary. Most of us are business men as well as engineers. We have our business interests and clashes of interests, our rivalries and jealousies, like other business men. In the consideration of principles, particular matters may be discussed by us that will touch one or the other closely. Our forum, however, must be a forum for all of the membership, and its discussions for the good of all. The truth is our aim and the seeking of it our work. Within our doors a perpetual truce should prevail, and the sword and buckler of everyday strife is to be laid aside at the threshold.

In carrying on our work I am sure I voice your sentiment when I say that there will be no feeling of jealousy between ourselves and our brother organizations, The American Society of Mechanical Engineers and The American Society of Civil Engineers, whose field in a way embraces our own, unless it be that fair and honest emulation to be of use to the world.

Our deliberations are confined to a special branch of applied science, of which each member is supposed to have special information, and matters pertaining to such can be taken up in greater detail and discussed with greater authority by a greater number than would be perhaps possible in the older and larger organizations. The result of our labors, the same of all kindred societies, cannot but be of mutual benefit, and I think I am safe in saying that we will go hand in hand.

A graceful recognition of this attitude has been most markedly shown by The American Society of Mechanical Engineers in many ways, including their kind permission to meet under their rooftree.

I am sure that this brotherly courtesy will be appreciated and reciprocated by this Society as a body, and by us as individuals.

In conclusion, gentlemen, allow me to quote our Constitution: "The object of this Society is to promote the arts and sciences connected with Refrigerating Engineering."

To that cause we have pledged ourselves. Let us go forward with hope and energy.

No. 2.

PIPE LINE REFRIGERATION.

By John E. Starr, New York, N. Y.
(*Member of the Society.*)

The scope of this paper is limited to a discussion of the distribution of refrigeration by pipe lines laid, by virtue of public franchise, under the streets and public places of cities for supplying refrigeration to all classes of consumers, large and small, or, in other words, a public service distribution.

Only two methods have been employed for distribution:

a. Brine circulation.

b. Direct expansion.

Boston, New York and Philadelphia each have a considerable street distributing service by brine circulation.

The direct ammonia system is installed in Boston, New York, St. Louis, Atlantic City, N. J.; Baltimore, Md.; Norfolk, Va.; Los Angeles, Cal. It has been installed and discontinued in Denver, Col., and is now in the course of installation in Kansas City, Mo.

The length of mains installed is not entirely a measure of the importance of the plant from an income standpoint, as the income per mile varies greatly, depending on the shape of the distributing parish. It is regretted that a tabulation showing relation of income and length of main cannot at present be given without violating business confidences.

Omitting a very concentrated district of refrigerating demand in Boston and barren connecting lines in other cities an average of $12,000 gross income per mile is nearly correct.

The various installations range from 1 mile of mains to 17 miles.

Brine lines now in operation have the usual two-pipe flow and return system, with refrigerator coils connected in multiple. The brine is cooled in brine coolers of the shell and coil type. Brine pumps are of the triplex type, driven by direct connected engines.

The power required for distributing the brine varies directly with the head and range of the brine.

Assuming a range of 5 degrees between the outgoing and incoming brine and a head of 120 feet, we have $\frac{200 \times 120}{5 \times 33000} = 0.14$

horse-power per ton of refrigeration delivered to the brine as measured by the brine.

Depending on the efficiency of the apparatus, this will call for from 0.23 to 0.28 horse-power at the motor per ton of refrigeration.

The insulation of the mains is usually effected by laying the pipe in a wooden box and covering with an insulating material soaked in some moisture-resisting compound.

Hair felt soaked with a mixture of rosin and paraffine oil is successfully used in one case and granulated cork soaked in pitch in another case.

The waterproofing compound is necessary to prevent the moisture of the ground from being absorbed by the insulating material and thereby destroying its insulating value.

Above ground all service lines must, of course, be insulated to and from the wall of the refrigerator. About all of the common forms of brine pipe insulation are here represented.

There is little information on the loss of refrigerating power by reception of heat coming through the insulation of mains. This loss is constant on a given length of main for each division of temperature of the atmosphere, but varies directly as to percentage of total load with the load—that is, the greater the load the less the percentage of loss. Accurate thermometer readings of brine temperature in the mains at the station and at various points on the line are needed to establish this interesting point. An attempt to arrive at it theoretically from the known insulating value of the covering would be frustrated by the unknown insulating value of the ground surrounding the insulation. It is suggested that careful research in this direction would be of great value.

Piping and fittings of various kinds have been used, both wrought and cast iron. In the latest installation (that at Philadelphia) a new form of cast-iron pipe was successfully installed. This pipe has at one end a slightly tapered boss, and at the other end an equally tapered recess, both accurately machined. Bolt lugs are cast on the pipe near the ends, the taper is inserted into the recess, bolts are drawn up and the joint is complete and very tight.

Owing to the fact that this joint under test showed great flexibility, it was at first thought that the joint itself would take care of expansion and contraction. This idea was quickly dispelled as soon as the brine was turned on, for the strain of contraction pulled off the lugs in several places. In further installation piston expansion

joints were used at intervals of about 175 feet and the trouble from broken joints ceased.

Practically all of the ammonia lines have been laid under what has been termed the three-pipe system, consisting of a liquid line carrying the liquid ammonia under pressure by main and branch to the expansion valves at the refrigerators; a return or vapor line carrying back the gas; and a third line called the vacuum line.

The expansion coils in the refrigerators are connected in multiple between the liquid and the vapor line. The vacuum line is connected at each expansion coil on the coil side of the stop valves on the liquid and vapor lines. Repairs at any refrigerator can thus be made without disturbing the balance of the system. The vacuum line is also connected at manholes for repair purposes on the main lines. It can be used as a bridge line to carry liquid over a block where there may be a leak on the liquid line. Its use is also imperative in extensions of existing lines, to carry air or ammonia to test out new lines without disturbing the operation of old ones.

The ammonia lines are laid in a conduit of vitrified or salt glazed split sewer pipe. The lower half of the conduit being first laid in concrete, then the ammonia lines are run and tested, then the top half of the conduit is laid on and cemented. Manholes are provided at street intersections in the usual manner of all street service work.

The expansion piping is rather liberally installed, the idea being to have enough piping to superheat the gas to nearly the temperature of the box and prevent frosting out into the return main. The patrol who handles the expansion valves acquires considerable skill in their manipulation, and as a rule is successful in holding the frost well inside of the refrigerator and allowing the gas to become so superheated that there is no frosting on the vapor service line leaving the refrigerator. In small refrigerators, however, it is very difficult to prevent frosting out, and wherever possible such boxes are connected in series with other boxes. Where a number of small boxes are grouped, as in a hotel or restaurant, a brine cooler is installed, fed from the street lines, and brine circulation is used locally.

Laying out the central station as to tonnage of machinery and provision for increase involves a study of average weather conditions. The annual output must be divided into periods showing average demands by periods, and, of course, the plant must be machined for the highest daily load and for the absolute peak.

It has been found that the Signal Service temperature reports offer a scientific basis for forecasting the distribution of the load through the year for various localities, especially where (as is most

often the case) the refrigerators in the distributing parish are directly affected by outside temperature conditions.

By taking the average mean monthly temperatures as shown by the Weather Bureau for a number of years and subtracting from each monthly mean the figure 30 (a little below freezing) the remainders will represent the distribution of the load by months. Working these figures into percentages of the total, we have our monthly load curve. Incidentally, it may be said that these percentages indicate very clearly the relative monthly volumes of the sale of ice.

A study of figures deduced as above shows that the July and August averages are the greatest percentage of the total in the north and diminish as we go south, where the curve flattens and the load is more evenly distributed throughout the year. Absolute peaks are obtained by using the mean of the three hottest consecutive days which are given out by the Weather Bureau in its regular statistics.

For laying out piping for the distribution of liquid, a drop in the pressure between the condenser pressure and the pressure due to the highest temperature likely to exist at any point on the liquid line is to be taken as a basis for the friction head. Considerations of static pressure are also involved and must be taken into account. As most installations so far are on comparatively level ground, this latter item has not figured extensively, but it carries a limitation, if liquid lines running to the upper stories of high buildings are involved. Such lines cannot be carried to a height where the loss of head would involve a pressure below the boiling point of the liquid at the temperature surrounding the pipe.

The temperature of the mains in the conduit seldom rises above 75 degrees in summer. This corresponds to an ammonia pressure of 126.5 pounds. With a condensing temperature of 150 pounds, the distribution of a given tonnage, or its corresponding amount of liquid, could be calculated on a drop of 23.5 pounds, but as it often happens that here and there liquid service lines run through warmer areas of temperature, it is not safe to rely on the temperature of the mains. In practice, therefore, a drop of 15 pounds has been considered about the outside allowance for friction head. There always remains, in case of change of conditions, the alternative of raising the condenser pressure to keep the ammonia in liquid form up to the expansion valves. Given the head as above, the problem resolves itself into one of hydraulics.

On the return side of the system the question of friction head is one of possible back pressures at the station and temperatures to be

maintained at the farthest refrigerator. It is manifestly desirable to hold the back pressure at the station as low as possible in order to obtain the greatest available friction head, thus keeping down the cost of line and also retaining the ability to give low temperatures at refrigerators far from the station and to keep down the cost of expansion piping. For this reason the absorption type of machine has been used largely for pipe line systems, as it possesses the advantage of working with economy at low back pressures.

If a policy of avoiding freezing business at a distance from the plant is maintained (which is really only a small portion of the total demand), all other classes of refrigeration, say from 28 degrees up, can be carried on the basis of 25 pounds for the highest pressure on the return line and 5 to 10 pounds at the station, giving a friction head of from 15 to 20 pounds. An allowance of 15 pounds for friction head is entirely safe under these conditions, and the ordinary methods of figuring the flow of gases in pipes cover the case. This figure allows freezing business, except on extreme ends of the line, and permits a reasonable cost of piping, both as to size of return line and amount of expansion piping.

In comparing the tonnage required to a unit of space refrigerated, or a unit of insulated surface in the refrigerators, a wide variation of results is found. In small boxes the size of the box is not a governing factor as to tonnage; conditions of use, number of times of opening and closing, and many other items enter into the question. As most all street lines include the large with the small boxes, satisfactory averages are hard to obtain, since, as there are no individual meters, the total output of the machine can only be compared with the total space refrigerated. Taking one plant, however, where the proportion of very small boxes is not large, some figures of interest can be presented. This plant supplies refrigerators ranging in size from 1,000 to 40,000 cubic feet, the average being 4,900 cubic feet.

In July and August one ton of refrigeration takes care of 2,800 cubic feet of space, or reckoning the area of the top, bottom and sides, one ton takes care of 1,128 square feet of insulated area. One cubic foot of space requires 0.07 tons per annum; one square foot of insulation requires 0.204 tons per annum.

The most important question in direct expansion pipe line work is that of leakage of ammonia. In fact, experience has shown that the financial success of the system must stand or fall on this item. In the first installations a class of fittings was employed that were intended to give flexibility to the line and to allow for expansion and contraction. This system involved a construction whereby, under

expansion, the line would tighten up in one set of packing and in contraction the line would tighten up on an opposing set.

When lines were carefully laid, this system seemed to fully answer all requirements, and for upward of five years lines laid by this method remained fairly tight. After the expiration of that period, however, it became gradually apparent that the life of this class of joints was nearing the end. The continual motion of the line under varying pressures and the very large movement when ammonia was withdrawn for repairs and the pipe temporarily greatly reduced in temperature brought alternate compression and release on these packings—their elasticity departed, and they were no longer effective. The leakage items became larger and larger until they reached a commercially dangerous point. To relieve this difficulty expansion joints of the piston or U bend type were introduced, but they only partly solved the problem. Finally a system was adopted of anchoring the pipes at definite intervals with expansion joints at definite distance from each anchor, confining the expansion and contraction to definite distances and to calculable limits. The latter developments include welding the pipes in a continuous length from manhole to manhole, and putting expansion joints at the manhole or U bends on the run. This seems to offer the most satisfactory solution of the difficulty and prevents the large item of leakage.

Of late apparently successful attempts have been made to weld the pipes *in situ* by the "Thermit" welding process. This process consists in thoroughly cleaning the ends of the pipes and butting them together. Strong clamps hold the ends firmly, one to the other. An iron mold is then clamped around the pipe, having an annular opening all around the joint. The Thermit is then poured into the mold from a hand crucible. The lighter slag first pours out of the mold, followed by Thermit steel, which sinks to the bottom, filling the mold about half way up with steel, and the displaced slag fills the balance of the mold. The great heat of the Thermit brings the metal of the pipe to a welding heat. The clamps are drawn toward each other, compressing the butted ends of the pipe, and the weld is complete. The mold is divided at half section. The upper part of the mold is taken off and the slag knocked off, as it is not adherent to the pipe. The lower half of the mold is then knocked down, carrying the Thermit steel with it, leaving a smooth weld.

This method presents the great advantage of welding the pipes in their situations in the conduit and avoids the rather clumsy hand welding and handling of long lengths. It seems assured that these methods will reduce the trouble from leakage to a satisfactory point

and will confine all leakage to manholes, where it can be readily detected and repaired.

While undoubtedly the major cause of loss from leakage has resulted from worn-out or badly put-together joints in the line, as a result of expansion and contraction there will always remain a certain amount of what might be termed insensible leakage. By insensible leakage is meant that leakage which is extremely small when each case is referred to, but in the aggregate is an item to be reckoned with. This leakage is one so small that the ammonia quickly diffuses into the air, and it requires the closest "nosing" or a searching local chemical test to find it. While this will doubtless always exist, its aggregate will not be sufficient to cut a large figure in line expense.

DISCUSSION.

The President.—Gentlemen, all these papers are open to discussion, and it is to be hoped that as they are read a lively discussion may be provoked. A paper read at a meeting of this kind that passes unchallenged, in a certain way goes out as with the authority of the Society. Therefore, I think that these papers should be closely scrutinized. Unfortunately, at this meeting we have not the advantage of having previously placed in your hands the printed papers to be read, in order that you might be prepared for discussion; but it is earnestly hoped that the members, while papers are being read, may make notes, either to ask for further explanation or for criticism, and I think that a large share of the success of our meetings will come from the critical discussion of the papers which are brought before us.

Gardner T. Voorhees.—While you were speaking I made a couple of notes. Your paper was so extremely fair, not siding with either the brine pipe system or the direct expansion pipe system, that there could be no possible criticism, but I wish to make one or two remarks from my own experience, particularly with reference to brine street pipe lines.

In Boston, when I was with the Quincy Market Cold Storage Company, we laid 1,500 feet of three 10-inch line pipes of the bell and spigot type, well insulated, through the streets of Boston. These pipes were used to supply cold storage warehouses, one of which was, as I remember it, of about a million cubic feet capacity, and two others which I think aggregated around half a million cubic feet.

The refrigeration that was put through that line was not what

you would call a large amount of refrigeration for the line. I tried several times to see how much loss there would be by the brine going from the main station to these warehouses. I used ordinary commercial thermometers, which I would say had about one-eighth inch of a scale division to a degree—possibly it was two degrees—but I would say that from my observation I was never able with a thermometer of that sensitiveness to see any loss in temperature. Of course, there was a loss in temperature, but it was so exceedingly small that thermometers of the ordinary commercial type, with degrees of an eighth of an inch, did not register the loss so that I could see it.

I want to speak of the difference between using a direct expansion ammonia pipe line and a brine pipe line, and I take it, from your paper, that there is a possibility of from 15 to 20 pounds loss from friction of gas coming from the distant expansion coils to the machine, whether it be an absorption or a compression machine.

If you assumed that you ran your station machine at 5 pounds back pressure on an ammonia pipe line, and if you assumed that there was 15 pounds friction on your pipe line, you would be able to run an ammonia pressure 15 pounds higher on your brine cooler or brine tank in a brine pipe line system than you would in the direct expansion pipe line system, which would mean that you would get about 40 per cent. more refrigeration from a compression machine if it were operated on a brine pipe line than if it were operated on a direct expansion pipe line, because of the fact that at the plant you would, with the brine pipe line, get the direct pressure of the ammonia without the loss of friction, while in the direct expansion street pipe line you would have to run the compressor at a considerably lower pressure at the plant in order to allow, as you say, for a sufficient friction head for the gas to flow to the machine.

The President.—It seems to me that the point is very well taken, as to the operation of a street pipe line with a compression machine; that the heat could be taken up by the machine on a higher plane if operated on a cooler.

It is perhaps hard to set a hard and fast figure of 15 pounds, or any other number of pounds, for the reason that there will, of course, be two exchanges of heat through exchanging surfaces—two in one case, while in the other there is only one temperature of the brine in the coolers.

A cooler nowadays is doing fairly well if it brings brine down to, say, 5 degrees of the theoretical boiling point of the ammonia, and the corresponding amount of back pressure would, of course,

have to be deducted in the case of the brine which the gentleman has spoken of, and it brings the results somewhat nearer.

I have stated this allowance of 15 pounds, and I meant to have made it appear that this was the outside friction head which it would be well to figure on, and would provide for a considerable extension of the business upon the pipe lines as laid; as a matter of fact, if properly laid out they run on considerably less head.

I have in mind one or two very large plants where the difference only averages about 5 pounds. I have also in mind one or two other plants where business has been thrown on without any particular regard to the size of the line, and where there have been differences as high as 30 pounds.

W. Everett Parsons.—In regard to the difference between the two systems, the brine system and the direct expansion ammonia system, of course we have to take into account the power required to operate the brine pumps, and, whereas it might require more power to operate the ammonia machine with direct expansion, it is a question whether that extra power would be any more than would be required to circulate the brine.

Louis Block.—How did you ascertain the loss of ammonia which you mentioned? How did you know that the loss took place under ground?

The President.—I will answer this, gentlemen, by saying that the only thing that we do know about it is, that on all lines so laid the record books have shown losses considerably in excess of the losses in plants of the same tonnage where the refrigeration was confined to the plant. We also know that large leaks have occurred on the lines, which would account for losses. The exact amount of difference between the amount of ammonia lost on the line and the amount lost in the central station can only be guessed at. There is a general loss which is both in the station and on the line. All we know is that the loss is larger per ton of refrigeration, or gets to be larger, as the system became older.

Louis Block.—What was the type of joint at that time?

The President.—The type of joint used largely at that time was, I think, what is known as a sleeve union. This was a type of joint something after the pattern of a "Boyle" union, but it had a double packing, one on each side of the ring, so that with expansion the line would tighten on one side of the packing, and on contraction would tighten on the other. These rubbers were enclosed in the sleeve and the whole system held up with a nut. These fittings for as long a time as five years gave very little trouble.

Louis Block.—When taking them apart, in what condition did you find the rubber?

The President.—We found the rubber had lost some of its elasticity, and while it was not vulcanized, it had been pressed and released such a countless number of times that it got to the point where there was really a clearance each time between the expansion and contraction.

Louis Block.—If you used flanges with lead rings and sufficiently heavy bolts, and drew them up tight, would not this answer the same purpose as a solid pipe?

The President.—Such joints have been more in use lately, and are much more successful than the joints originally used, but the feeling, I think, has been growing among those operating street pipe lines that, as between manholes, the line must be simply above suspicion. There must not be any question about the joints, about the possibility of bolts breaking, about the possibility of here and there a weak flange breaking in two. I have alluded to this matter of welding as a comparatively recent proposition, and I am not fully able to say how thoroughly and how much we should do to obviate the difficulty.

Louis Block.—Has it been tried?

The President.—It has been tried within the last year, and so far it has done very well.

R. L. Shipman.—I should judge that the welding would be far superior to any temporary joint. What is the comparative cost of the two joints, the welding and the one that Mr. Block speaks of? The one with the lead gasket would probably have to be a very neatly fitted joint with very heavy fittings.

The President.—I may say that the cost of hand welding the pipe is not so very much in excess of the present cost of a fitting, together with the labor of putting it together. It all depends on how you are prepared for doing this welding. The Thermit process, which I have alluded to, is very much simpler than hand welding. It is extremely simple, but the cost of the Thermit is rather high. At the same time, it does not come far from the expense of an ammonia fitting and the labor of putting it together. I think Mr. Greene may be able to tell us more exactly about it, as he has had some experience with Thermit.

V. R. H. Greene.—From the little experience we have had with Thermit we have come to the conclusion that with small pipes, half-inch and inch and a quarter, Thermit is much cheaper than the Boyle union. These pipes are so small that they can be filed to a

close fit so as to prevent any leakage through the pipe. Thermit costs about $1 per weld for inch and a quarter pipe; and my impression is that the union without the labor is about the same price.

The President.—The sleeve type of joint is rather less.

V. R. H. Greene.—By comparing the cost of Thermit with Boyle fittings in the case of 2-inch pipe, we found the Thermit was cheaper, costing $1.40 per weld as against $1.68 for a fitting. When we came to use 4-inch pipe we had to use a face plate, and that brought the cost up very considerably. As it takes about 10 pounds of Thermit to make a 4-inch joint, the expense would be $2.50, without the cost of labor. Therefore, when the pipes are large, I imagine standard fittings would be less expensive than Thermit welding.

Edgar Penney.—I would like to ask about the rusting away of a pipe by coming into contact with moisture, either interiorly or exteriorly.

The President.—Experience on the rusting of pipe has been somewhat of a puzzle. In a large number of the older insulations the pipe came out, after laying eight or nine years in a dry conduit, and painted when it was put in, in a perfectly dry condition, as dry as this room; in some places the pipe was in perfect condition. In Atlantic City, where a system of this kind was installed twelve years ago, I expected that the pipe would have a very, very short life, for the reason that the tide of the Atlantic Ocean runs through the island, and in many cases runs into the conduits and out of them, the pipes being between wind and water, and salt water at that; and while a great deal of trouble was experienced, it was not really as much as was expected.

We have had one or two cases of electrolysis, where some vagrant current reached the ammonia pipe. In fact, one bad leak occurred from that very thing. A piece of an inch and a quarter extra strong pipe was cut clear through, the score running almost half way around the perimeter of the pipe. On the whole, however, I think that the trouble from rusting out has been less than might reasonably have been expected.

Edgar Penney.—In a threaded joint the scale is removed and it is very susceptible to rust. It is one of the disadvantages of that joint.

Henry Vogt.—I would like to ask how long such a pipe line has been in use; what is the oldest line in operation?

The President.—The oldest line was laid in St. Louis in 1889

and 1890; that is the oldest ammonia line I am speaking of now. I think there were some brine lines before that.

Henry Vogt.—Is that pipe still in use?

The President.—There is some of that pipe still in use. Some of it is in very good condition, more especially in the dry portions of the conduit.

Edgar Penney.—What do you use for waterproofing the pipe; what is found most effective for covering the pipe when it is laid?

The President.—I do not believe I can answer that question. I take it that some of the gentlemen here have gone over the subject of pipe coatings. If any gentleman can answer that question I would be only too glad to hear from him. I have never yet seen a perfectly satisfactory pipe coating, and pretty near everything was used as covering on these lines as they came along; all the various carbon coverings, their name is legion, all guaranteed to last forever and resist acids and alkalies and everything else. I have never seen anything, excepting in a dry conduit, that would last.

W. T. Robinson.—Are you referring, Mr. President, to a paint or coverings?

The President.—Paint.

Edgar Penney.—Have you had any experience with pure coal tar?

The President.—No; I remember none.

Edgar Penney.—My impression of coal tar is that when the iron surface is dried perfectly and a good thick coat applied it is very favorable. A tank treated in this way was in use for probably fifteen years, and was then replaced by a larger one, and when the old tank was dug up the iron, after scraping away the paint, was found to be as clean as the day it was passed through the roll. Coal tar seems to be as good as anything, in my experience, applied upon a perfectly dry surface in two or three coats.

Gardner T. Voorhees.—We have a member with us to-day who I happen to know has made extensive investigations of the painting of surfaces. If Mr. Haven could give us an idea of his experience it would be found very interesting.

Harry M. Haven.—I told Mr. Voorhees at the start that I intended to remain in the background as much as possible and talk but little. The results of extensive tests which we made on all kinds of paints for iron work can be summed up in a very few words by saying that almost any paint would adhere to clean and perfectly dry surfaces, but when it came to painting surfaces that were in damp places there seemed to be a filament of moisture which would

be precipitated on the pipe, or on the surface before we could get the paint there, so that the paint would not adhere well.

If you can dry the surface perfectly, almost any good paint will adhere if allowed to dry hard. In shops where boiler plates are made it is customary to mark them with white lead; this mark will remain indefinitely because the plate was perfectly dry and clean; but when a pipe is put in a conduit the surface has a certain amount of moisture, and this stratum of moisture gets there before the paint can set. That has been my experience.

W. T. Robinson.—Have you ever used "Bitumastic" paint? It is the paint used by the United States Government in the coal bunkers of their ships. We have experimented for a number of years with various kinds of paint on iron surfaces, and we have found the Bitumastic paint, which is a coal tar preparation, far better than any other.

Harry M. Haven.—At the place where these tests were made, in the condenser room of a refrigerating plant, the conditions were the worst possible; the air was saturated with moisture. Copper paint, which is very expensive, and commonly used on the bottoms of vessels, would not stand. Carbon paint, even when the surfaces were wire brushed and carefully dried, would rapidly deteriorate. A quick drying paint would seem to lower the temperature of the metal enough to carry it below the dew point of the atmosphere, and that would cause this stratum of moisture, which I speak of, to form, and a slow drying paint was not suitable because it would not set quickly enough to stay for any length of time on the pipe.

L. Williams.—With reference to the Bitumastic paint: I have had considerable experience both on shipboard and on shore installations. On refrigerated vessels where the hull is sealed up, and where it is a most expensive proposition to get at it, it has been found in English practice that Bitumastic solution, which is probably the paint referred to, is most successful. But it is most important that the bloom be off the plate first, and the steel or iron thoroughly wire brushed before painting. Some think that one coat is just as good as two. When put on a plate which is reasonably dry and clean the Bitumastic solution seems to hold better than any other paint. This opinion has been arrived at after about twenty years of experience.

An interesting experiment was made in London some seven years ago with six pieces of 2-inch pipe. Two were covered with Bitumastic solution, two galvanized, and two subjected to the "Barfing" process. One sample of each was placed in a brine tank, and

another sample of each was suspended on the outside wall of an ice factory, where it was subjected alternately for six hours to the tidal water and air. After a period of six months the various samples of pipe were carefully examined, and while the galvanizing was found to be entirely gone, the Barfing also gone, the Bitumastic solution was only covered with a sort of slime, which, on removal, showed the pipe and Bitumastic solution covering to be in first-class condition. It has been found to be the general experience that Bitumastic solution must be applied to thoroughly wire brushed and dry plates in order to get good results.

W. T. Robinson.—I have used the Bitumastic solution for a number of years, and we have never found any serious trouble in its application. The point that Mr. Haven makes, that the pipe must be perfectly dry, has not been proven in our case. There was a certain percentage of moisture on the pipe, and although we brushed it with a wire brush some moisture still remained. I thoroughly endorse what the gentleman has said about the material.

The President.—How long does it last; through what period? In speaking of pipe line matters, of course, when you put things away underground you hope never to see them again, and it is a little different situation from reaching a condenser or reaching some surface which could easily be repainted at intervals. When I spoke of the difficulty of finding a perfect coating, I referred more particularly to the long life of the coating, to a longer period of years, rather than to a satisfactory result of, say, a year or so.

W. T. Robinson.—This solution was first called to my attention by its use in the coal bunkers of ships. In the English service, with soft coal, the sulphur is very active in destroying all kinds of paint. I cannot answer how often it has to be renewed, but in my experience, where we used the very worst kind of water, we would renew the paint every winter, and found that the pipe kept in perfect condition. I should say that in conduits it would be a success.

No. 3.

ELEMENTS GOVERNING THE SELECTION OF THE "PLATE" SYSTEM AND THE "CAN" SYSTEM.

By Edgar Penney, Newburgh, N. Y.

(Member of the Society.)

Preliminary to selection, the principal features of each system should be understood. This paper will, therefore, describe each system without going into technical details of construction and mechanical variations employed for making ice by the "plate" system or the several modifications of apparatus employed in the "can" system. The title of the paper assigned by your Programme Committee, and the limited time allowed for reading, preclude this, admitting only a very general explanation of the essential features.

The "plate" system derives its name from the practice of freezing water against the exterior face of a metal plate, maintained by means of mechanical refrigeration at a temperature below 32 degrees F.

The "can" system freezes water in open top metal cans, generally rectangular in shape. These are exposed to freezing temperature, either by partial immersion in a mechanically cooled non-freezing liquid bath, in a properly cooled room or in the open air, when below 32 degrees F.

A distinctive feature of peculiar importance is that when plate ice is frozen from one side only it is an exact substitute for natural ice, both in keeping and in transparent qualities.

An elementary difference of vital importance in plate and can ice is the result of radical departures in process. Plate ice having its growth in thickness from one side only, the exterior face being always in contact with free water, the formation of ice proceeding from the freezing plate outward, certain undesirable properties of the water held in solution, or mechanically suspended or other than chemically fixed, are separated and rejected by the slowly freezing water and pass into and are taken up by the residual or unfrozen water, which, at the termination of the freezing period, is drained off, the tanks then being refilled with fresh water. In waters

heavily charged with carbonates, etc., as, for instance, lime, clear crystal ice can be obtained by a slower rate of freezing, thus giving time for elimination, provided there is a larger percentage of residual water to take up the impurities scoured off without becoming oversaturated, or provided there is a more frequent change of water during the stated run.

In the "can" system, in which all the water in the rectangular can is frozen, the formation of ice proceeds simultaneously from the four sides and bottom in a peculiar prismatic formation, the impurities rejected by the water finally being frozen in the centre of the mass. To dispense with this centre core makes necessary the various and sundry complications connected with the "can" system, and limits the possibility of economic production compared with the "plate" system, in which all water fit to drink can be used without distillation, ordinary filtering being all that is required to produce crystal ice. The same quality of water when frozen in cans reveals in a surprisingly unexpected manner to sight, smell and taste visions odoriferous and unsavory. The problem, therefore, in the "can" system is to disassociate dirt and water before the molds are filled, based on the theory that pure water will make pure ice; and so it will, but how to purify water on the large scale required in the modern can ice factory is a vexatious question. The following is a recipe in use by some experts: Boil the water. Some undesirable properties doubtless vacate when served with such a dispossess notice, but others cling to their tenement—in fact, invite harsher treatment. Boil harder! Boil longer!! Boil into steam!!! Remove the tenement, leaving the hardened tenant behind. Distil, filter, reboil, filter again, purify, store, forecool and fill from the bottom of the can slowly to prevent re-aeration. Then freeze, melt, smell and taste the core. But distillation for the "can" system necessitates steam boilers, and the number of pounds of water to be boiled into steam must equal the pounds of ice to be made plus the waste, say 25 per cent. additional.

Water wheels, gas, oil or other cheap motive power are available for driving plate ice plants, but with the "can" system, when pure ice for family use is a necessity, such powers cannot be utilized, as the inevitable steam boiler for producing distilled water must be installed, and it would be complication more confounded not to use the boiler steam required for distillation to drive the pumps, ice machinery, etc., on its way to the distiller, taking the energy out of the steam by doing this work and have as many pounds of steam left for ice.

The principal elements in the selection of the "plate" system and the "can" system may be contrasted as follows:

Quality of Ice.—Both systems, under intelligent management, will produce ice of good quality, but the "can" system depends upon a complicated arrangement of distilling and filtering apparatus, which permits of rapid deterioration in quality if not carefully watched and kept in effective working condition.

Stored Ice.—Plate ice possesses the desirable quality of keeping in storage equally as well as natural ice without resort to mechanical refrigeration to prevent rotting and crumbling. This good point permits the manufacture of plate ice to be carried on during the entire year, if suitable well-insulated ice houses are provided. Can ice, on the contrary, from its lack of homogeneity due to formation or peculiar mitre-like joining of the four sides and bottom and centre core, does not lend itself favorably to storage. To prevent disintegration and preserve a good quality of clear ice, the ice storerooms must be maintained by mechanical refrigeration at a point equally as low as the freezing tank where frozen.

Cheap Power.—Water, gas, electricity, or any cheap motive power, can be used for producing plate ice, but when distilled water is required, the "can" system *must* use steam; therefore the economy of the distilling steam boiler is the only factor of fuel cost.

Water.—Where water is highly impregnated with lime, etc., or contains gaseous products capable of vaporization and condensation, the "plate" system can be used if operated at a slow rate of freezing, as, for instance, sea water can be frozen on the "plate" system, while very opaque ice is produced and the water is difficult to handle on the "can" system.

Investment, or First Cost.—For producing ice 12 to 14 inches thick the investment is greater in the "plate" than in the "can" system, where steam is used, by 33 to 75 per cent. This is due largely to the increased area of buildings required, high pressure compound condensing steam engines, power traveling cranes, expensive construction of freezing tanks and cells, etc., or, in other words, in the "plate" system the highest priced and most economical type of labor-saving apparatus and steam engines can be used, with a resulting increase or return from investment.

Investment Returns, Operative Economy.—The comparative economy in pounds of ice made to one pound of coal burned is for the "plate" system, with highest class special equipment, 14 pounds of ice to 1 of coal, or, with average high-grade equipment, 10½

of ice to 1 of coal. The average "can" system uses about 1 pound of coal to produce 6 pounds of ice.

Ground.—The "plate" system requires, when arranged in a one-story structure, about double the ground for buildings as is required for the "can" system.

Cash Available.—Given a limited cash capital, and a desire to keep out of debt, you are enabled for one-half the money to build and equip a "can" system of same tonnage capacity, occupying but one-half the space, but bear in mind you can operate a "plate" plant the year round, storing the ice, with half the capacity and at same cost.

Ice for Cooling Cars.—When crushed ice is required solely for cooling purposes the "can" system is by all means the cheapest to operate, as the ice may be made in thin, quick freezing molds, the distilling system and steam boiler dispensed with, and any motive power used for driving the compressor.

Short Operative Period.—An element to be taken in consideration in choosing is the proper tonnage capacity of a plant to suit the demands of a locality. If, for instance, the average demand during the working season of four months is 50 tons daily, and in the height of the season a maximum of 100 tons or more, it would be advisable to purchase a 75-ton plant on the "can" system in order to serve and keep your trade.

A 25-ton "plate" system installed in connection with a well-insulated ice storage house would serve this same demand when run through the whole year, storing the surplus ice and realizing the great economy of utilizing the cold winter weather, which largely assists the freezing and condensing apparatus.

The most important element, however, in the selection of the "plate" system or the "can" system is yet to be named, and that is the purchaser. Generally, he is a law unto himself, and ofttimes without regard to local conditions selects the worst system and the wrong capacity, with resulting financial loss. We suggest that the choice of systems is governed by local conditions, other things being equal, such as cash capital, land, demand, etc.

The "plate" system is specially desirable where cheap motive power can be had other than steam; where the factory is run at full capacity during the entire year, the surplus ice being stored for future delivery; where an absolutely uniform quality of ice, not dependent upon the skill of the operator, is a necessity for securing and keeping trade in competition; where a larger dividend

upon a larger invested capital is desired; where plants of very large capacity are installed.

To secure best economy in large "plate" system installations, the equipment should include a power hoisting crane for lifting ice from tanks; automatic machinery for sawing large cakes into blocks; power ice handlers and conveyors; ample and well-insulated ice storage rooms; the main tank freezing cells, plates or coils thoroughly well made with a view of long life and avoiding leakage; abundant forecooling water storage. Where steam must be used, adopt a high pressure water tube boiler and the best make of compound condensing engine, preferably of the Corliss type.

The "can" system may be selected where the demand for ice is small and capital limited; where cracked ice is made for icing cars, filling cold storage boxes, etc., or for other than domestic use or where the distilling system can be dispensed with; for export in small units; where it is necessary on account of limited ground space to build high with several tank rooms on different floors; where ice factories are run only during the rush season.

Plate Arrangements.—In closing, it may be of interest to touch upon the various plans in use for freezing water in large cakes, ranging from very small to 10x16 feet and 14 inches thick. Many of the schemes are particularly interesting. The usual construction for plate plants is to provide a long, water-tight tank of wood, stoutly built, one style being about 9 feet deep, 17 feet wide, and any desired length, divided by bulkheads into compartments, the intervals between these being regulated by the number of freezing surfaces required to make up the plant's rated capacity, when harvested daily from a single compartment; for example, a 24-ton daily output. Time allowed for freezing, eight days, ice 12 inches thick, and size of cake 8x16 feet. Harvesting and waste allowed give 500 pounds for each inch in thickness, or 6,000 pounds net per cake, 48,000 pounds daily. The net output calls for eight surfaces, or four double-face cells to a section, and a total of thirty-two cells for the entire plant, not allowing for a relay or spare section.

Plate cells are made up in various ways:

a. Tight cells. Really narrow water-tight boxes, say, 16 feet long, 8 feet 6 inches high, and 3 inches between sides. Open on top for inserting a close laid zigzag coil, the space being filled with brine.

b. Cells of similar construction, but the coils are omitted; brine circulated.

c. The tight cell is removed and a close coil or series of pipes take its place. A thin plate of metal on each face to insure smooth freezing surface.

d. Metal faces omitted; ice forms directly on the coils.

e. Tight cell with bottom drain. Cold brine allowed to trickle in a thin sheet down inner surface.

Where pipe coils are used the freezing medium may be either ammonia by direct expansion or brine.

Another modification is to have the cell detachable, the tank of large size and no partitions, the cell being lowered into the tank of water and the ice forming on cell sides. When the ice is of sufficient thickness, the whole is lifted from the tank and a new cell lowered in its place; the ice-laden cell is then emptied of brine, ice thawed therefrom and cell made ready to replace the next one harvested.

Another plan is to lower a rectangular, water-tight box, partly filled with water, into a bath of cold brine, the ice forming on the inside surfaces, but removed some time before the water frozen surfaces come in contact, the space between containing sufficient water to take up the impurities. This arrangement will be recognized as a modification of the "can" system, but on a larger scale and different method.

Still another plan is to take horizontal tanks, open at tops, provided with wheels and fill these with water and roll into a specially designed cold room. The bottom and sides are insulated, so freezing occurs on upper surface only, the water impurities settling at the bottom.

There are various other "plate" schemes of more or less merit.

The construction of the freezing apparatus of the "can" system is quite simple compared with the "plate" system, and consists of a shallow insulated tank of wood or metal containing pipe coils placed in rows with a space between them for receiving the cans. The tank is charged with strong brine, which is cooled by the circulation of brine or refrigerating gas through the coils, and cans of water when placed in the brine are frozen. Or the coils may be omitted entirely, and the cold brine circulated through the tank.

A curiosity, called the "block" system, is a plan in which the cans and brine are omitted and the tank filled with water, which is frozen in a solid mass and cut into blocks by steam thawing devices, the blocks being pried loose and lifted from the tank by a special hoist.

And there are others too numerous to mention in this paper.

DISCUSSION.

Thomas Shipley.—Regarding the elements governing the selection of plate and can systems for making ice, I will say that my experience with these two systems has convinced me that, unless water or electric power can be obtained to drive a plate plant, it is not good policy to install such a plant, for the reason that the cost of the maintenance of a plate plant is so much greater than that of a can plant that it more than overcomes the difference in the coal consumption required for its operation. And, unless a plate plant is kept in perfect condition, the can plant will turn out more ice per ton of coal in a year's time than a plate plant. I have also decided in following up the sale of plate ice in competition with can ice that, unless the quality of the can ice is not up to the present standard, the best that can be gotten from a customer is the option at the same price. Of course, in some localities where they have had very bad can ice, plate ice has the preference; but as a dividend payer, the can ice plant is the better of the two.

The block plant, as you know, is a compromise between the can and the plate systems, and, in my opinion, is a very much better investment than a plate system, even where water or electric power is obtainable and it is desirable to make ice out of filtered water.

Regarding the space required for these plants, I will say that with can plants, where the usual expansion coils are used, fourteen 300-pound cans to the ton is our allowance.

Where the expansion coils are fed by the flooded system, that is, instead of expanding into coils the ammonia is fed into a reservoir, and from there it gravitates into the coils, twelve 300-pound cans per ton are sufficient.

In the counter-current system, where the brine is cooled in a separate compartment from that in which the ice is made, and the cans are made to travel toward the coldest brine, ten cans per ton are sufficient.

In plate and block plants we are using from 250 to 275 square feet of freezing surface per ton.

The cost of these plants, based on 50 tons capacity, would be about as follows:

Can system, $550 per ton; block system, $650 per ton; plate system, with direct expansion plates, $800 per ton, and the brine plate system, $1,000 per ton.

You will understand that all of the above prices would be

varied in accordance with the completeness of the plant, and whether or not it was up to date in every respect.

As to the fuel economy, I will say that a good plate plant will produce about 10 tons of ice per ton of coal, and a good can plant about 7½ tons of ice per ton of coal. This is with water at 60 degrees F. and with the best steam coal.

Louis Block.—The economy does not seem to agree. Mr. Shipley said 10 tons was the best he could do, and Mr. Penney said 10½ to 14 tons. I think that point should be discussed between the two.

Thomas Shipley.—I will say I only stated from my own experience what I would be willing to guarantee. I did not state what might possibly be done by somebody else.

W. T. Robinson.—I would like to ask Mr. Penney if, in the modern standard of ice making, they have succeeded in eradicating what I always call in my layman's phraseology the creosote odor in the can ice?

Edgar Penney.—The creosote odor?

W. T. Robinson.—In every core will be found more or less of an odor, depending upon the care with which the ice is made, but I have never been able to find a cake of ice in which it is entirely absent.

Edgar Penney.—Is that without any regard to the quality of the water and the locality where the ice is made? Is it present in all can ice?

W. T. Robinson.—In all that I have ever examined.

Edgar Penney.—Perhaps you refer to that flat taste peculiar to distilled water?

W. T. Robinson.—Not at all. That can be taken away by aeration. I have tried it and succeeded. Sometimes it is very difficult to detect this odor, but it very soon develops, and, to my thinking, it is the one objection to the can system. I have tested ice in all parts of the country. Whenever I found an ice plant I always looked for this one thing.

Edgar Penney.—Have you had it analyzed so that you can say that it is creosote?

W. T. Robinson.—No; I have always considered that the smell arose from some organic matter cooked in the water. I would like to find can ice in which it is absent.

Edgar Penney.—In the reboiling at the open circuit it should be eliminated. It is one of the conditions in the can system that requires careful watching and ever present vigilance.

W. T. Robinson.—According to your standard, it is not present if everything is in good shape.

Edgar Penney.—I say it is possible to produce a chemically pure water, which, when frozen, will make pure ice; but that requires constant vigilance on the part of the operators. This property that you speak of is the same as is present in any filtering apparatus, or in anything that is employed to eliminate impurities. The function of that apparatus is to arrest it, so that it does not pass on through. Now the time may come when filters become surcharged, and impurities pass on to the can. In any system of evaporation, if you have two large filters, you can use one to-day and the other to-morrow, changing off and cleaning. But, no; you go along the line of least resistance, if I may call it that, and simply make ice that will sell. Only when the trade begins to kick do you look around for the cause of the trouble and seek to improve your product.

A. P. Criswell.—I think I understand what Mr. Robinson means. He does not mean that there is an odor in the block of ice as a whole, but in that little impure part that you always find in the bottom of a block, and sometimes in the top. I think he is quite right. If you take a cake of ice from any locality and split it at that point there is an odor. I have never seen a block of ice that did not have an odor that was detectable if you break it at that point, while the balance of the ice, if that is cut off, will be perfectly pure.

John C. Sparks.—I have always noticed it. Any smell that appears in the core of the ice would arise from the organic matter in the water. There are many spring waters that contain no organic matter. If there is much smell then the charcoal filter needs renewing. If that is not renewed the smell will be retained. One can always tell whether there will be any smell in the core of the ice or whether there will not. In many waters that have practically no organic material in them there will be no organic smell in the water. If you take any surface water, such as Croton water, the organic matter will be split up in distillation and will come over, and that needs oxidizing by some process on the way from the boiler to the water storage. If that is done the smell is eliminated. Of course, the smell is in the middle, because the process of freezing water is natural elimination, the pure water being frozen on the outside and the impurities gathering to the inside. That smell would be expected there, and can be very easily overcome. I do not agree that it is present in all ice.

Louis Block.—I agree with Mr. Sparks. There is one water in the United States on which no charcoal deodorizers are necessary, and that is in the city of Memphis. In the city of Newark, N. J., when it used Passaic River water, which was so bad that it was guaranteed to contain one rotten egg per gallon, I say you could make out of that water absolutely pure ice, with absolutely no smell, but you could not do it for more than six or seven days in succession. Then you had to renew the charcoal in the deodorizer. As long as you had your charcoal deodorizer in good condition you could make pure ice. If your water is pure to start with you will make pure ice; if it is not, you will not without the use of a deodorizer.

Gardner T. Voorhees.—I think the matter of the smell in the core of can ice, regardless of how good the water is, or how clean the deodorizer is, depends on another matter. It depends upon the keeping of the boilers clean; the cleaning of the boilers ever so often. It is unquestioned that the animal and vegetable matters held in suspension in most waters are decomposed in the boiler into gases, one of which undoubtedly is ammonia gas, and some of which undoubtedly is not thoroughly eliminated in the reboiling. I believe if the boilers are thoroughly cleaned once in two weeks or once a month anyway, and if they are frequently thoroughly blown off, a good part of the smell and odor in the core will be avoided. Except in very rare cases and with very pure water the smell in the core can never be entirely avoided at just one particular point, as Mr. Criswell said. That one particular point will seem to gather all of the odor, just as the bitter gall would be gathered in the gall bladder of a chicken.

I just made some figures on the possibilities of producing so many tons of ice with so many tons of coal. If you take the position that you will lose 25 per cent. weight of water in making your ice, then in making one ton of ice you will need 2,000 pounds of water, plus 25 per cent., or 2,500 pounds of water. I consider that a first-class boiler will not evaporate more than 10 pounds of water per pound of coal. By dividing 2,500 by the proper figure you will find that it will be impossible under those conditions, having a boiler that will evaporate 10 pounds of water to one pound of coal, to get better than 8 tons of ice for one ton of coal in any can ice plant. If the evaporation is one to eight, as is considered good, I believe that it will be impossible to exceed 6.6 tons of ice to a ton of coal, which figure, I believe, corresponds very well with Mr. Penney's remarks as to the general capacity of can ice plants.

Henry Vogt.—Referring to the can ice and water question, it

is very clear to my mind that the water regulates largely the quality of the ice. In fact, I know we have some machines that do not use any filtering apparatus for the water, and turn out ice very satisfactory to the trade. In other cases we have put in filtering apparatus to give sweet water, and customers complained of the quality of the ice. A customer visited plants in which the charcoal apparatus had been done away with and then began to make ice as the other man did, and the complaints would continue; and then the customer called and wanted to know why we had not built him a plant such as the other man had. I told him if he would use a similar water and employ the same methods his ice would be as good.

John C. Sparks.—With respect to the question of ammonia coming over from the boiler, there is usually a small percentage of ammonia in all waters, due to the decomposition of organic matter. In cases where there are three one-hundredths of one grain per gallon of 58,600 grains it brings it down to one ten-thousandth of 1 per cent. of ammonia in the water. If anybody can detect the smell of ammonia they have wonderful organs of susceptibility in regard to ammonia. The ammonia will come over, of course, but the organic gases can be very easily eliminated, so that the question of ammonia in the water is really not a bit serious.

W. T. Robinson.—I beg to differ with the gentleman who has just spoken on the question that there is no reason why organic gases cannot be eliminated. If the water we use in Philadelphia, which is the receptacle of all the filth of Philadelphia's drainage, is to be treated, it is a very serious problem. I have given every attention to this matter for years. We have reboiled, aerated the water, changed our filters every five or six days, used sponge filters, done everything we could think of and could learn from others which would benefit us, and still this odor would be very pronounced. It is undoubtedly the organic gases. I do not believe this trouble can be entirely eliminated in any of the larger cities.

Louis Block.—Where do you get your charcoal?

W. T. Robinson.—From dealers in Philadelphia who supplied it, and from a number of different sources. It was of a thoroughly good quality.

Louis Block.—We have had charcoal that did not deodorize anything.

Edgar Penney.—Do you use the charcoal that is used by the whiskey distillers? What they do not know about charcoal is not worth knowing.

W. T. Robinson.—I consulted a number of people supposedly

up on the question of filtration, and I believe we got the very best quality of charcoal.

S. J. Rowe.—I have found that by using alum as a coagulant and then filtering the water through sand, before the water passes through the steam boiler, and then using an effective reboiler, the smell can be absolutely eliminated from can ice.

George Berna.—Is it not finally coming to a question of analyzing the water and finding out by that what really constitutes the impurities which cause the smell? In almost all can ice there is a smell. It is not always caused by the water itself, but it may come from boiler compounds or oils; in fact, many different elements are involved, probably from dozens of sources. Would it not be best to study every plant by itself, and then compare notes?

Louis Block.—I believe that the gentleman is quite right in saying that each particular case has to be treated by itself. I do not know of any two cases that are exactly alike. We never attempt to make pure ice without analyzing the water and determining what is to be done in each particular case. Filtering the water prevents the accumulation of dirt in the boiler. While I have no doubt that some of the odor comes from a dirty boiler, we always suppose that the ice maker looks after that part of the business and keeps his boiler clean and filters the feed water.

Henry Vogt.—Mr. President, if you are through with the water subject I would like to ask Mr. Penney a question. I understood him to say in his paper that in freezing plate ice he could use salt water. I would like to know to what extent?

Edgar Penney.—Do you want to know whether it has been commercially applied?

Henry Vogt.—I had that in mind.

Edgar Penney.—I do not know of its being commercially applied. I simply say that the plate system can be used in the making of fresh ice from salt water.

Harry M. Haven.—I would like to inquire if chlorine comes into the question at all. I note in the analysis of drinking water it is customary to use chlorine as the measure of contamination; that is, the chemist goes into a district, and makes what he calls a chlorine map. I would like to know whether this is the real element which determines the purity of the water, and whether it can be eliminated by any process of making can ice?

John C. Sparks.—Chlorine is always present as a chloride of sodium. Chlorine is only one of the indications of sewage. If there is much of the albuminoid of ammonia, which is ammonia

that has not undergone its final decomposition, it indicates the presence of sewage. The presence of nitrous acid is one indication of contamination. The question of chlorine is always taken into consideration, because in connection with those other two points, the albuminoid of ammonia and the nitrous acid, one is able to judge whether the water is contaminated or whether it is not. Chlorine may be present in large quantities, and only indicate chloride of magnesium or sodium, and so it would not indicate that the water was contaminated.

Mr. Penney said that when water contained an excess of carbonate of lime the freezing should be done more slowly. I think the salts of magnesium have much more effect than the salts of lime, and I think that the quality of water has much to do with making good plate ice. If there is much magnesium in the water, even if the freezing is done very slowly, the ice will be slightly opaque anyhow, and so the quality of water should have a good deal of bearing on the selection of either a can or a plate ice plant.

W. Everett Parsons.—I would like to ask Mr. Penney whether, in making a comparison between the can system and the plate system, he took into consideration the fact that a plant has to be shut down for a certain length of time during each year for repairs. It usually requires about two months of the year to repair and overhaul a plant that has had to run continuously every day for the remainder of the year, and besides we have to account also for the costs of handling the ice in the storehouse and from the storehouse, and the meltage of the ice while it is in the storehouse. All these things have quite an important bearing on the cost of plate ice as compared with can ice.

Edgar Penney.—I am not familiar with any ice-making plant that requires two months out of twelve to effect repairs. I have never been associated with one of that kind, so that Mr. Parsons probably knows more about that than I. Regarding the melting in the storehouse of storage ice, that, of course, has to be allowed for the same as you would for natural ice. The handling in the ice house, which is done by conveyors, is a very small expense.

I was speaking more particularly about the repairs of an ice plant. In a can plant there is scarcely anything to be repaired, even if the machine is operated 365 days in the year, that cannot be taken in detail, except possibly the freezing tanks. If you have but one tank, and that tank starts to leak, you would have to strip the tank in order to stop the leak. If anything happened to the boilers, you generally have a spare boiler to fall back on. You can lay off one

while you are fixing it and go on with the other. You could always do that with an ordinary compressor, which consists of two parts, so that you can run continuously, the same as you could a factory or a ship.

W. Everett Parsons.—I think there is considerable difference between the machinery of an ice plant and the machinery of a ship or a factory. The machinery of a ship is shut down at the end of every trip, and there is an opportunity for making repairs for three or four days, while the machinery of an ice plant may be required to run for six months, and should run, if possible, without stopping at all.

I speak from experience in handling an ice plant from a commercial point of view, and having to handle it from year to year. I found it necessary to shut down for about two months every year and go over every part of that plant in order to be sure that it was going to run until the next winter, and I found out that the safest way, and the only safe way, to operate a plant was to do that every winter.

In handling the ice in the house and out of the house, there is considerable waste in addition to the melting. There is considerable breakage. My experience is that it costs about 25 cents a ton to store the ice, to hold it from early spring until midsummer, and take it out of the house again, but then my experience was with a can plant.

Edgar Penney.—Might I ask the capacity of that plant?

W. Everett Parsons.—Seventy-five tons.

Edgar Penney.—Might I ask if you kept your organization together during the entire year? Did you discharge the men at the end of the ice-making season?

W. Everett Parsons.—Not all of them.

Edgar Penney.—You had to keep a number of men on the pay-roll. They might as well be handling ice as anything else.

W. Everett Parsons.—Yes.

Edgar Penney.—What was the nature of the repairs that took two months that could not have been done if you had been forced to run the machine the year around?

W. Everett Parsons.—If I had more than one machine I could probably run the whole year, but not at the full capacity. Every part of the machine has to be examined. There is wear and tear, and that has to be taken care of.

Edgar Penney.—Everything made by the hand of man has to be kept up. There is no peculiarity about that; there is no question

about it; but there are lots of cases where machinery quite as complicated is kept in motion the year through, just by looking ahead a little and getting some spare parts, and watching the opportunity to stop for half an hour to repair this or that, or even to disconnect parts of the machine. It must be quite a peculiar case to have so long a period for repairs. I will admit that there is, perhaps, wisdom in shutting down once in a while to clean house, rather than taking a little time now and then if the conditions were favorable for doing it, but I have never been brought in contact with a plant which required so long a period of housecleaning.

W. Everett Parsons.—I do not know anything that will run continuously; at least, not heavy machinery.

Edgar Penney.—The machinery that pumps water direct for a city without a reservoir is seldom shut down. Shutting down the pumps means no water in the homes, no work in the factories. The thing has got to go; it does go by hook or by crook. There are other instances which probably you could call to mind. The machinery from the moment it is started has got to thrash along until another is provided for emergency. Ice plants are run for six months under these conditions. The rush season is on, and it has got to go, and it does go. If it will run six months it will run twelve under the same care.

W. Everett Parsons.—I think an ice plant can be made to run six months if put in proper condition during the winter, but if your argument holds good you could run it for twelve years without stopping. You simply cannot do that.

The President.—The time for the discussion of this paper is nearly up, but I feel that we would not like to leave this subject without hearing something from Mr. Briggs, who has handled rather a large amount of ice.

John N. Briggs.—I did not want to do any talking, but since the subject came up I may say I have had some experience in making commercial ice, and in handling natural ice, and I will tell you what little I do know about it. I have had some experience in operating ice machines of different kinds, and my experience is that it is necessary to make a stop every year in handling a compression machine to clean the coils internally. In handling any kind of a can plant dirt will accumulate in the tank. You need to clean the tank, to clean the coils and paint them, and that all takes time.

Now, in regard to the expense of putting plate ice into a building, I know of no way in which you can take plate ice from the manufacturing room, store it and take it out at less than 25 or 30 cents a ton, to say nothing of the waste in the house or of the rent of

the building. You cannot put up a building, insulate it properly and get a proper return for the investment at less than 15 cents a ton. To house plate ice, pay the rent, and take it out will cost you at least 45 cents a ton besides the waste, and your waste will be at least 20 to 25 per cent., according to the conditions of the handling.

I am handling natural ice. I have 100,000 tons of ice put up in my own buildings, and I have been handling from 100,000 to 120,000 tons a year every year for the last twenty-four years. I cannot get out of the best building I can build over 78 per cent. of the spring measure capacity; but that, of course, is in delivering in New York City. Your deliveries here are platform deliveries to the wagon. You can, of course, make a saving in the meltage. I have to stand the meltage in transit, also the meltage in boats in the harbor here, as well as in the ice house.

No. 4.

COLD STORAGE REQUIREMENTS FOR THE REFRIGERATION OF PERISHABLE FOOD PRODUCTS.

By W. T. Robinson, Philadelphia, Pa.

(Associate Member of the Society.)

The first cold storage expert, and therefore the patron saint of The American Society of Refrigerating Engineers, was Dame Nature herself, for long before primitive man came into the world to begin the study of thermodynamics, the wise old lady was storing in her icy coverings the animals and fish which are being found to-day in perfect preservation, and furnishing to the scientific world evidence of prehistoric life that could not otherwise be known. Nor in the thousands of years that have passed since in Nature's laboratory man first learned the value of frozen water in its ability, under certain conditions, to produce low temperatures, has any material development been made in the production of cold air for commercial purposes until within the last generation.

We do not have to search very far for this sudden evolution of the old ice house into a modern cold storage. The earnest study and daring and successful experiments of members of your Society have revolutionized artificial refrigeration and given to industrial history one of its most interesting and important chapters. Cold storage, as we know it, is a very considerable factor in the economic development of the United States, the value of perishable products stored amounting to over $200,000,000 annually. Many millions of dollars are now invested in the preservation by artificial temperatures of fruits, eggs, butter and meats, and every year large additions to the available space for this purpose are being added in all parts of the country.

Cold storage is still in its infancy, and I do not believe that any of us can realize at this time the importance and growth of this business in the near future. It, therefore, behooves us to give our best thoughts and energies to the study of the problems presented by the practical application of the laws of chemistry and mechanics we are now applying.

Until a few years ago cold storage, as applied to food products,

was obtained entirely by the use of ice, and if the warehouses were properly constructed the results at certain seasons of the year and for moderate temperatures were much more desirable than in many of the warehouses operated with mechanical refrigeration to-day. They, at least, by the melting of the ice absorbed the objectionable odors and created a circulation and humidity of the air which is absent in the airtight rooms of to-day. Unless cold storage rooms are equipped with the means to properly regulate the humidity and remove the impure air and gases that accumulate in large quantities, dependent on the nature of the goods stored, a modern cold storage warehouseman cannot expect to obtain the best results or furnish his patrons with the most approved service.

But with the development of mechanical refrigeration came the ability to obtain much lower temperatures than with ice, and the tendency of our customers has been each year to demand the extreme low degree our plants can furnish. This, too, without any willingness to pay for the service, until now we are giving zero temperature and below for less money than ten years ago we were able to charge for 25 and 30 degrees. The revolution in temperatures is still going on, and the managers of a freezer warehouse must be able to furnish 10 to 15 degrees below zero at all times of the year if they are to be in position to meet the demands of their customers. I do not believe it is necessary or desirable to carry butter or meats at a temperature much below zero, if the air and humidity can be properly regulated, and the reason for the demand for the lowest possible temperatures, and the better results shown by goods held at very low temperatures, has been that quick freezing does not permit the goods to be so susceptible to the air of the room.

Perishable food products that are usually placed in cold storage can be divided into two classes: those having life, such as fresh fruits and eggs, stored at moderate temperatures; and those not having life, such as cheese, butter and meats. The former are live organisms and require fresh air for their preservation, just as much as animals and human beings. Fruits and eggs breathe, and if the carbon dioxide thrown off by them is not removed, and a fresh, sweet air with plenty of oxygen in its composition given in its place, the goods have to absorb again their own impurities. As a result they deteriorate and lose their keeping qualities. In the renewal of air in a warehouse, especially if bunker rooms are used, great care should be exercised in removing all impurities and odors before it is admitted. Excessive moisture, either in the rooms or hallways, must be absolutely avoided. Nothing will injure the keeping qual-

ities of cold storage products so quickly as dampness. Dead matter, such as butter, poultry and meats, does not require such frequent renewal of the air as do fruits and eggs, but the proper degree of humidity is just as important to their keeping qualities.

Certain kinds of food products are directly benefited by being placed in cold storage, while others are not improved by their exposure to cold temperatures. Eggs, fish, butter, and some varieties of small fruits are always at their best when perfectly fresh, and although cold storage retards their depreciation in value as a food product, yet we cannot claim that they are benefited. Strawberries and peaches rapidly lose their flavor when exposed to the cold air, while some other fruits, such as winter apples and pears, are improved by the transformation of their starch into sugar. I have experimented with eggs, and have carried them for twenty-three months without showing any appreciable change, except a shrinkage in their contents of about 25 per cent. Poultry and meats are improved by exposure to cold temperatures, and cheese, when fresh made, can be better ripened if placed in a cold room, but the latter article when it has reached its maturity is not improved by cold storage. I have carried butter for two years, and have sold it for the full market value without its quality being questioned by the buyer. I would add, however, that the market was very firm at the time and the trade was not very critical.

Although my text refers only to the preservation of food products, yet there are several uses to which cold storage has been applied in the last two or three years that are interesting, as showing the development of the business. For instance, in a Western city large quantities of cut flowers are placed in cold storage and are held for a considerable time to meet the extensive demands of the holiday seasons. In another Western city the Catholic churches store their wax candles during the summer months. My own company has for several years carried fruit trees in cold storage in anticipation of the spring planting. We have also carried huckleberries, frozen at a temperature of 20 degrees, and used for pies by the bakers. Another use for cold storage that I have been experimenting with has been the curing of hay fever patients. I am much encouraged and believe it can be made of great service to the many sufferers who are now forced to leave their homes for the north country during August and September.

Experiments made by the experts of the United States Agricultural Department during the last two years have proved that quick freezing is the proper method for preserving meats, poultry

and butter, while for eggs and green fruits, the nearer the freezing point they are held without danger of being frozen the better will be the results.

I would especially call the attention of this Society to the splendid work Secretary Wilson, of the United States Department of Agriculture, and his able body of experts are doing in their experiments on the effects of cold storage on food products. They have reached a point where they cannot obtain the needed information owing to the impossibility of securing the proper rooms and temperatures at any of the commercial cold storage warehouses in the country. It will be necessary for Congress to furnish an ample appropriation to equip the Agriculture Department with a cold storage plant of its own where the needed temperatures and humidities can be obtained. I would respectfully suggest that this Society adopt suitable resolutions commending the United States Agricultural Department for the good work it is doing, and requesting Congress to appropriate sufficient money to give the Department the necessary equipment to carry on its investigations.

A very important question, and one that every warehouseman must carefully study and watch, is the condition and history of the goods placed in his care, for, no matter how perfect his service may be, if the contents of the packages are not in proper order for storage his efforts will be of no avail. If, for example, the fruit has not been properly picked at the right degree of ripeness, or after picking has been too long delayed before being placed in store, or has been grown in a section of the country where the conditions of soil and climate will not furnish the best keeping qualities, the results cannot be satisfactory. Again, if the animal heat is not withdrawn from meats and poultry before delivery to store, and they are not properly packed, quick freezing will injure the goods, the outside freezing and the inside retaining its animal heat until decay sets in.

The style and size of the package are also important factors. Quick ripening fruits should be packed in shallow crates or baskets with plenty of open work for ventilation. Meats and poultry should also be stored in shallow packages, so that the cold air can quickly penetrate into every part. On the contrary, butter stored in bulk in solid packages retains its flavor and gives much better results than if in the form of prints in shallow packages. In freezing poultry and meats, it is most important to spread the packages for several days before being finally piled, for if the boxes are tiered immediately when received in the freezer room the cold air does

not quickly penetrate into the centre of the pile, and there is danger of some of the goods being damaged before they are properly frozen.

Under the old range of temperatures, from 15 to 40 degrees, a warehouse could be constructed so that the rooms were interchangeable for different classes of goods at different temperatures, and could be economically operated with one temperature of brine; but now that minus 10 degrees is demanded you should have your house divided into different sections for low and moderate temperatures, with the system of cooling arranged separately for each.

Some warehousemen claim that they can and do carry different kinds of goods in the same room, for example, eggs, cheese and apples, without being affected with each other's odors. This is a dangerous experiment, and I cannot believe that the results can be satisfactory, even if the temperatures of the goods have been reduced to the same degree before storing in the same room.

Insulation is a very important factor and is not always given the necessary consideration in planning a cold storage plant. Several of the new houses have been carefully insulated on their exposed surfaces, but their designers have paid little attention to the floor insulation. This is a serious mistake, unless an entire vertical section is given up to the storage of the same kind of goods at the same temperature. But with the ever-increasing variety of commodities offered for storage, with their different odors, it is a serious handicap to not be able to use any room or series of rooms because of the danger of injury from foreign odors. High rates of insurance, and the ever-increasing cost of real estate in the large cities, will make it necessary in the future to use only fireproof construction in the building of cold storage plants. This is a comparatively new development, and we should make a careful study of the best materials, and their combination, to enable us to furnish an economical and efficient warehouse.

Architects, consulting engineers and owners, when designing a refrigerating plant, must give the closest attention to the factors which enter into its successful operation. In these days of small margins and fierce competition, the value of real estate, construction of buildings, economy of operation, class of business to be carried on, and cost of fuel and water must all be carefully considered.

The insulation should be of the best, both for protection from heat and for durability. The plans for receiving and delivery platforms, size and location of the cold rooms, hallways and mechanical

department, local conditions of exposure and location and railroad connections are all vital to the success or failure of the business. First cost is everything, for on it owners must figure dividends. The greatest mistake that can be made is to sacrifice efficiency of insulation and mechanical capacity for a saving in the original price per cubic foot. The coal pile and repair bill will, when it is too late, soon demonstrate the expensiveness of the error.

Although in theory the commercial side should not have to be considered by the expert, yet I feel it is his duty to warn his clients if he believes, after investigation, that the geographical location and earning capacity of the proposed warehouse will not warrant the expenditure. It does not add to the reputation of the architect or engineer if the plant he designs proves a failure, although the commercial conditions may be entirely to blame.

Irresponsible promoters, or promoters and capitalists, who do not fully understand the cold storage business in all its phases, will, without proper investigation, invite the public, under highly colored statements of big dividends, to subscribe to their ventures, and often build large warehouses at points where it is impossible to legitimately operate them at a profit. There are a number of such establishments throughout the country to-day, which, through poor service and the adoption of ruinous business methods in the struggle to show a return on the investments of the stockholders, are bringing discredit on well-managed and conservative warehouses whose locations are warranted by the demands of the trade.

Constant vigilance is the secret of success, and I would urge on everyone interested in this important business to lend every energy to the further perfecting of the plants the operating man has to depend on for his results.

DISCUSSION.

Henry Vogt.—I would like to hear from Mr. Robinson as to what success he had in curing hay fever.

W. T. Robinson.—This matter was called to my attention last year by a friend who had been a great sufferer from hay fever, and who, by accident, was cured by going into the hold of a vessel, a refrigerated liner, to make interior measurements, and where he had to be continuously in a cold air for two hours. When he came out his hay fever was entirely cured; he did not suffer from it again that summer. This occurred several years ago, and every year when he felt the fever coming on he would go to a cold storage

plant to be cured. It struck me as a pretty good scheme, and I have practiced it on a few patients, but I am not clear as to what temperature they should be exposed. I furnished them with heavy clothing and made them promise to keep moving, for I do not wish to have any deaths charged up against me. We kept them in cold storage for two hours, starting with a temperature of about 34 degrees F., and moving them from one room to another until they were exposed to a temperature of about 25 or 26 degrees. One patient was cured and another was afforded great relief, the fever returning later, but in a less degree. The third patient has not reappeared. He came to us in his heavy clothes and asked for a trial; afterward he went away apparently happy, and I have not seen him since. I intend to make other experiments. It is on the theory that we know that the first frost cures hay fever. At the first touch of frost the sufferers are made well. The question is whether an exposure to a cold temperature and then a return to the warmer conditions will cure; but so far as I can see it is going to give great relief.

Henry Vogt.—Do you charge by the cubic foot?

The President.—I would like to inquire of Mr. Robinson something in this line. He has told us that the operating cold storage warehouseman requires certain things from the operating engineers, and from the designing engineers, especially in regard to questions of humidity. It is admitted that so far as temperature is concerned the refrigerating engineer is pretty capable of producing any temperature, but I think a little more enlightenment as to conditions of humidity required for certain goods expressed in terms of percentage of humidity would be a guide to many of us, and I would like to know if Mr. Robinson has any specific figures in his mind as to proper humidities for various products, such as eggs, fruits, etc.

W. T. Robinson.—I consider, Mr. President, that the question of humidities is very much in its infancy, and whatever humidities we use now I think are more by rule of thumb than by accurate readings. In the use of the hygrometer I have found by experience that it is hard to take accurate readings, although I have used one for many years. You can only tell by experience the conditions of your room. I cannot tell how large an amount of humidity certain goods require.

Louis Block.—How do you obtain the humidity? How do you get it if you want a certain degree?

W. T. Robinson.—You can get it by the introduction of outside air into your bunker. The air will be dried to a certain degree, but

it will depend upon the amount that you allow to enter. By watching it mixing with the air you can get a proper humidity. I do not think you can get it too dry.

Louis Block.—I should think that your air would be in danger of becoming very dry.

W. T. Robinson.—Of course, the introduction of air into freezing rooms is a different matter from its introduction into rooms in which fruits or eggs are stored, or what we call moderate temperatures. Certain fruits require a dry air, and so do eggs. If you get the air too dry it absorbs too much of the substance of the eggs, and dries them too rapidly; but a dry air is much more desirable than air in which there is an excessive amount of dampness present, because that creates mold and must, and all the other evils which the warehouseman most dreads. The United States Agricultural Department is most anxious to investigate humidities. I do not think any of the commercial warehousemen to-day are equipped to take up this question, and yet I believe it is one of the most important fields we can go into, and one which is practically unexplored to-day.

Louis Block.—I should think one of the most difficult procedures would be to regulate the moisture as you want it. The introduction of air from the outside is too uncertain, because the conditions outside change.

W. T. Robinson.—Dry the air before blowing it in, then you can heat it up in a confined space so as not to let it reabsorb and cause damage. You can reduce the air by contact with cold substances to zero, and yet introduce it into rooms at 28 degrees. At zero you have very little moisture, but at higher degrees it increases rapidly, so that if you introduce air at 25 degrees you can obtain a very considerable percentage in the air, and you can control your moisture in that way, if you know how much you want; but I do not believe anybody has any data on the subject that are accurate. I have tried to obtain such data for years, but I have not been successful.

Louis Block.—To keep it at a point of saturation is a simple matter, but to keep it at a point below saturation seems to be a very difficult matter.

W. T. Robinson.—That is the problem. I hope our friends in the Agricultural Department will solve it. I know they are anxious to begin. They have discussed with me how to regulate the quantity of moisture by the absorption of moisture from blankets saturated with water. It is going to take us a long while to tell how much moisture per cubic foot is necessary for the preservation of eggs and fruits. The dry air is what we now try to obtain.

Louis Block.—It will dry out your eggs so much faster.

W. T. Robinson.—It will, if you have a circulation.

Louis Block.—Have you any figures of the loss by weight per month?

W. T. Robinson.—Not per month, but it runs from 5 to 7 per cent. at the end of five or six months, during the storage season. It is then represented by the snow on the coils of your rooms or your bunkers. It will run from 3 to 4 pounds on a case of eggs weighing originally 50 to 55 pounds.

Louis Block.—You stated that things do not improve by cold storage, except apples or pears; all the other things are not improved. Do you mean to say that they are injured, for instance, cheese and butter?

W. T. Robinson.—That depends.

Louis Block.—Peaches and strawberries you have said are injured.

W. T. Robinson.—Peaches and strawberries are injured, and butter, as I said in my paper. Those classes of goods are never so good as when they are fresh; but, by the best standard of cold storage that we know of, we can retard the depreciation so that there is not very much loss.

Louis Block.—Does it get worse and worse, or does the deterioration simply stop?

W. T. Robinson.—If you freeze the butter at a very low temperature it at once takes an outside coating, and that delicate aroma which gives it its value is largely retained. There is a certain something lost; but if the room is perfectly sweet, if all the conditions of the cold storage equipment are the best, it can be minimized. Butter is never so good after three or six months' storage as it was when originally stored.

There is a very interesting set of experiments made by the United States Agricultural Department which will illustrate my statement. There was a special lot of butter made in Kansas, made in the same creamery and at the same making, so that it could be declared uniform in every respect. It was taken to a warehouse in Chicago and placed in different temperatures, ranging from 6 degrees below to 30 above zero. When it first went into storage there were three or four leading experts from the West who examined the butter, and it tested or graded 92 points. Then every month the same body of experts would examine it at these different temperatures. It was put in in September, and it was taken out on the 30th of the following April; that is eight months. Butter stored early in

September scored 92; when taken out the last of April at 30 degrees above zero it scored 75. That shows a very decided loss. At 20 degrees above it scored 75, showing that this was also an impossible temperature. At 10 degrees the butter scored 78; at zero 82, and at 6 below zero, 88. In other words, at the end of eight months there was a loss at 6 degrees below zero of only 4 points, which, I think, answers your question.

Taking poultry and meats, if you store them at a moderate temperature for a short time they will improve.

Louis Block.—Up to six or eight months?

W. T. Robinson.—Long enough to make them tender and to take out the animal heat. I would say two or three weeks. If you freeze them that is another matter, but I am speaking of 25 to 28 degrees Fahr. At very low temperatures meats and poultry, if they are carried a number of months, lose their flavor and their value as a food product. Take a squab or a tender broiler, and store it for a year; it will come out in a state of perfect preservation, but as for flavor, it is like a chip. They can be kept for a long series of months, but they have lost their flavor.

Harry M. Haven.—While I would like to speak principally as a designing engineer, I have had considerable experience from the warehouseman's point of view, especially with eggs, in connection with a large corporation which stored eggs in a warehouse having a million or more cubic feet. The system was to circulate the air round and round from the bunker room, dry the air with chloride of calcium, and convey it into the room with a humidity of 80 per cent. This humidity of 80 per cent. was reached through experiments covering quite a period and made necessary by market men who complained of a musty odor to the eggs. It was found from these experiments that when the air was too wet a certain white fungus, not pronounced enough to be called a mold, and which could only be observed by holding the eggs up to the light, was formed on the shell, while if the air was sufficiently dry, say 80 per cent., this entirely disappeared.

The method of obtaining a uniform temperature was by the circulation of a large volume of air. The addition of a large quantity of eggs to a room with a small volume of air would derange the temperature, whereas with a large volume of air it requires considerable heat to change the temperature to any extent. Having circulated this large volume of air, and having the coil room so designed that coils could be turned off or on, as required, realizing that the warehouse in the first place was well insulated, so that no

heat was lost through the walls, we were able to maintain the required temperature and the humidity.

The necessity of air locks became apparent. In some cases where they were not used more moisture leaked into the room than could be taken out by the chloride of calcium.

I wish to speak as a designing engineer upon the tendency to use indirect circulation for the preservation of fruits, of the necessity of using it in some cases and the advisability of using it in others. The necessity of using it is, I think, apparent in the case of eggs. It is becoming a necessity in the case of fruits. It seems to me that before a great while the most effective means of freezing will be by indirect circulation, perhaps a combination of indirect circulation with the direct. You will necessarily have to keep eggs separate, in a separate section. Perhaps fruit will have to be kept in a separate section. A great many frozen products can be carried in one room, the floors and ceilings of which must be well insulated on account of the different temperatures existing in the warehouse.

No. 5.

THE TRANSPORTATION OF FRUIT IN REFRIGERATION.

By G. Harold Powell, Pomologist in Charge of Fruit Transportation and Storage, U. S. Department of Agriculture.

(Non-Member of the Society.)

I am glad of the opportunity of bringing before a body of refrigerating engineers some of the problems that confront the fruit industry in the extension of the American fruit trade. I refer especially to the difficulties that arise in shipping perishable fruits under refrigeration.

The United States stands first among the nations as a fruit-growing country. No other country has developed the industry on the scale that our commercial orcharding has attained. The tremendous extension of the railroads since the Civil War, and the American aptitude for developing new industries, have opened vast geographical areas in the United States where fruits of various kinds flourish more abundantly than other products of the soil. California has a peerless reputation throughout the world for the products of her orchards and vineyards, western Michigan for its peaches, Florida for subtropical fruits, the Carolinas for the strawberry, and western New York for its apple orchards. Orchards are being planted throughout the United States more rapidly than ever before, and new horticultural regions are springing up in the East and in the West as the facilities of transportation are extended, and as irrigation and other improvements in modern agriculture make fruit growing possible where land was formerly unproductive.

The Demand for Fruit Increasing.—There are abundant reasons to suppose that the present period is not more than the infant stage of the American fruit industry. The demand for fruit is increasing by leaps and bounds throughout the civilized world. It is passing from a luxury to a staple food. In the United Kingdom the consumption of foreign apples has trebled in the last six years. The demand for various fruits has grown not less rapidly in our domestic markets. Our urban population is increasing more rapidly than ever, factories are building more numerously than

farms, thereby increasing the demand for fruits as never before. We have no statistics on the subject, but our impression is that the increased demand for fruit is more than keeping pace with the increased production from the areas that are constantly coming into fruitfulness.

The Export Trade.—There is an unlimited opportunity for the development of the export trade where the use of fruit has had a phenomenal increase in the last thirty years. Great Britain paid over $45,000,000 in 1904 for her imported fruits, of which about $5,000,000 worth, or less than 14 per cent., came from the United States. Her import fruit bill amounts to more than the total import and export fruit trade of the United States. Our foreign apple trade is the only fruit developed to any extent, the United Kingdom securing from the United States over 50 per cent. of the imports, which amounted to nearly $10,000,000 in 1904. We sent only about $70,000 worth of the $10,000,000 worth of oranges imported by the United Kingdom in 1904. The orange is the largest single import item in the fruit bill of the United Kingdom. The trade is monopolized by Spain, which furnishes from 85 to 90 per cent. of the supplies. American oranges are luxuries in European markets. The California navels are superior in size and appearance to the best European oranges, and are prized highly by those Europeans who are fortunate enough to know them. Here is a golden opportunity for the California navel and Valencia, two varieties of superb shipping quality. Of nearly $19,000,000 worth of miscellaneous fruits, such as the peach, pear, plum, cherry, and others, exclusive of the banana, imported by the United Kingdom, we send not over one-quarter million dollars' worth, yet our peach, pear, plum, and some other fruits can be exported under favorable conditions of transportation. The opportunities for trade on the continent of Europe are not less attractive, and the time is coming when there will be a big demand for American fruit in the markets that are tributary to the Pacific.

Overproduction the Result of Poor Distribution.—The future development of the American fruit industry depends on the ability of the producer to lay down his crops quickly and in sound condition in distant markets, both domestic and foreign. Efficient transportation is the keystone which must determine the stability of the industry. So-called overproduction is the result of an inadequate system of distributing a crop widely and safely. Inadequate transportation means temporary gluts followed by barren markets. Under a proper system of distribution there is little danger of the

overproduction of most kinds of American fruits if a high standard of grading and of quality is maintained.

Taken as a whole, the American fruit transportation service is the best in the world. We have the only highly developed fruit car service in existence. Fruit is distributed more widely, in quicker time, in better condition and at cheaper cost here than in any other country. The fruit crop requires special facilities for transportation. It is the most perishable commodity that the car line handles. It deteriorates quickly from overripeness or from decay. It must be handled carefully by the grower, it requires quick refrigeration and uniform service on the part of the car line, and rapid schedules on the part of the railroad. The fruit car service as a distinct part of transportation is hardly more than twenty-five years old in America. There has been gradual improvement along all of these lines since its establishment, but we have reached a time in the history of the fruit trade where considerable additional progress must be made in the methods of handling fruit for transportation, if the fruit industry is to develop to the largest extent through a wider distribution in domestic and foreign markets.

Weaknesses in the Methods of Fruit Handling.—One of the principal difficulties that the fruit grower or shipper has to face in extending the fruit trade is the limitation in the distribution of fruit on account of the ripening and the development of decay that may occur in refrigerator cars. In ordinary practice fruit is loaded in cars in a hot condition. It requires several days after the fruit is loaded to reduce the temperature of the fruit to a degree of cold that retards the ripening and the decays. During the first few days the car, especially in the top, is warm. The ripening springs forward during that time, and as the atmosphere is moist the rots may begin to grow vigorously. These are fundamental difficulties in the present method of handling fruits for transportation. They have a far-reaching influence on the development of the fruit trade. They limit the distribution of the perishable fruits, thereby preventing the greatest development of distant domestic and foreign markets. They also make it necessary to pick the summer fruits prematurely to protect against the ripening in transit, thereby placing enormous quantities of insipid, flavorless peaches, plums and other fruits before the consumer.

How the Peach Industry Is Affected.—I will endeavor to make these problems clear by a few specific examples. The Georgia peach is limited to markets within three to five days from the orchards. The fruit is shipped in carriers, usually loaded in the car

five tiers high. The peaches range from 75 to 95 degrees Fahr. when placed in the car. Under the best car line service the temperature of the fruit in the bottom of the car may drop to 40 or 50 degrees in two to five days. The temperature of the top tiers of fruit may be 10 to 15 degrees higher. On arrival at destination, especially with the early varieties, or in all varieties in wet seasons, the bottom tiers of peaches may be sound, while the top tiers may have developed from 5 to 30 per cent. of soft and decayed fruit. The bottom tiers could be shipped several days longer, but the distribution of the crop is limited by the probable condition of the fruit in the top of the car. We know that the Georgia peach can be stored safely in a temperature of 35 to 40 degrees Fahr. for two weeks. We know that the Georgia peach can be shipped to the markets of the United Kingdom, if the shipping season is favorable and the conditions in transit are right. The problem, therefore, that the Georgia peach grower would like to have solved is (especially as he has 20,000,000 trees that may bear in the next few years)—and the problem is equally important in all of the peach-growing sections in the South—how can the handling of the fruit be modified so as to insure its safe arrival in more distant domestic and foreign markets? On the solution of this problem will depend in large measure the permanent stability of the enormous capital invested in Georgia peach lands.

Let us examine the relation of the present methods of handling the California peach for transportation to the conditions of the industry. Grown in a semi-arid climate, the Pacific Coast fruit is dryer than the Eastern grown fruit. It has wonderful shipping qualities. The fruit is wrapped and packed in boxes that weigh 20 pounds when full, which are stacked in the car about ten tiers high. The fruit is distributed throughout the United States and Canada, and, to a limited extent, in European markets. The trip across the continent averages about ten days, and the entire trip to the United Kingdom less than twenty days. The California shipper has the same trouble as the Georgia shipper with the top tiers of packages. These tiers are often marked and sold separately. The fruit in them arrives in New York in all stages of maturity, from full ripe to moldy, while the peaches in the bottom tiers may be hard and sound.

The California peach is frequently loaded at a temperature of 95 to 100 degrees Fahr. At the end of five to ten days the temperature of the fruit may drop to 40 or 50 degrees. On account of the smaller package, the closer packing in the car, and the wrapper on

the fruit, it requires nearly twice as long to cool the fruit as it does the Georgia peach packed unwrapped in more open carriers. The California fruit, therefore, continues to ripen several days after loading, even when the bunkers of the car are filled continuously with ice. To protect against this ripening in transit, the peach grower has to pick the fruit at a very immature stage of development before the peach develops flavor, quality or the highest color. The fruit arrives with a flat, insipid flavor, giving the section the reputation for producing fruit of inferior quality. The Western peach is a luscious fruit when ripened on the tree. In the future competition between localities in the markets of the world such a region must appear at a disadvantage unless the fruit has some redeeming merit other than quality that makes it acceptable to the dealer and to the customer. The problem that the Western peach grower wants solved is—and this applies to other perishable deciduous fruits of the West—how can the fruit be handled after it has developed a high color and a hard ripeness on the tree so as to lay it down in sound condition in all parts of the cargo in distant domestic or foreign markets? On the solution of this problem depend the future development and the permanent stability of the peach business of the Pacific Coast.

The Effect on the Citrus Fruit Industry.—We will refer to the citrus fruit industry as a third and final example. The losses from decay in transit in the orange and lemon crops from California amount to about $500,000 annually. The orange is wrapped and is packed tightly in boxes that weigh 72 pounds when full. The packages are stacked on end in the car, usually two tiers high. After the first of March the fruit may range from 60 to 90 degrees in temperature when loaded. The temperature of the air in the refrigerator car may drop to 40 or 50 degrees in three to ten days, but the fruit in the centre of the package remains several degrees warmer for many days. As a result, the decay in the fruit in the top tier of packages is greater than in the bottom, often by 10 per cent., and worst in the centre of the package in both tiers. We know that the orange can be stored safely for many weeks at 40 degrees temperature if the fruit is stored quickly after picking. The problem that the California citrus fruit grower wants solved is: How can the fruit be handled so as to insure the safe arrival of all parts of a cargo in the most distant domestic and foreign markets? California now produces yearly 30,000 carloads of citrus fruits. The problem will need to be solved in the near future to prevent temporary domestic gluts by the opening of more distant markets.

We might multiply examples indefinitely to bring out the relation of the present methods of handling fruits for transportation to the limitation of their markets, but the typical references already made will indicate the nature of the problems we have in mind.

Losses Not All Caused by Transportation.—We would not leave the impression that all of the losses in transit in perishable fruit are due primarily to the conditions surrounding it in transit. On the contrary, many of the most important commercial losses from decay in the thick-skinned fruits, like the apple and the orange, are caused largely by the rough treatment of the fruit in picking and packing, thereby making it susceptible to decay. Fruit that is perfect physically may be landed in distant markets in sound condition even under adverse conditions in transit, but bruised fruit is likely to develop losses under the most favorable conditions in transit. We need to reform the methods of handling the fruit crop in America fully as much as we need to improve the transportation conditions. This phase of the subject is one, however, which cannot be handled in this paper.

Improvement Needed for Safe Transportation.—From the standpoint of the keeping of the fruit in transit, an economical, practical method is needed to reduce the temperature of the fruit more quickly after packing than is accomplished by the ordinary refrigerator car. A more uniform distribution of the air in the car is also needed. Nearly 400 patents have been taken out in the United States with a view to improvement in the refrigerator car service. The patents cover construction, air circulation within the car, ventilation, the capacity and arrangement of ice tanks, mechanical and chemical refrigeration, and various other subjects. There has been an enormous improvement in the efficiency of the refrigerator car since the first patent in 1867. The improvements have usually been attempted by modifying incidental features of existing cars, and those in practical use have been selected with a double view to efficiency in refrigeration and ease of adaptability to the requirements of modern railroading. Complicated mechanism, of which there are innumerable instances in the patents referred to, is apparently impracticable when applied to the modern refrigerator car. Anything that delays the movement of trains or is beyond the skill of the average brakeman to handle is clearly out of place. I do not care to express an opinion as to the possibility of improving refrigerator cars along the lines mentioned. I would refer those

problems to you gentlemen as expert engineers, and I would propound these questions for your further consideration:

1. Is it possible to construct a refrigerator car to be cooled with ice that will refrigerate a load of strawberries or peaches in hot weather quickly enough to check the rots and the ripening of the fruit in the warmest parts of the car?

2. If not with ice alone, then with ice and salt, with liquid air or by other methods of chemical or mechanical refrigeration, keeping prominently in view the fact that complicated mechanism is of doubtful utility in the handling of the refrigerator car service.

These things have not been fully accomplished by the 400 patents on refrigerator cars. If it is not practical to do so, then we would propound the further query: Should a refrigerator car reasonably be expected to accomplish the initial refrigeration of the most perishable fruits in hot weather and to maintain the refrigeration afterward, or, should we ultimately expect the refrigerator car to transport safely perishable products that are placed in the car in good condition for transportation? Under present methods of handling fruits, the losses originate largely during the period of slow initial refrigeration. In the fresh meat trade this difficulty is obviated by refrigerating the products before shipment and by maintaining a lower temperature in transit by the use of ice and salt. Perishable fruits from Australia to the United Kingdom are likewise refrigerated before shipment. Most of the Eastern grown Bartlett pears are refrigerated in warehouses before exporting. Bananas are now being cooled in train loads in transit, and it is proposed to refrigerate the cantaloupes in the semi-arid Imperial Valley of Coachella, California, before shipment to the East.

Cooling Fruit Before Shipment.—We know that many of the large commercial losses in perishable fruits in transit would be overcome if a practical method could be devised of cooling fruit efficiently and economically before shipment, provided an equal improvement in the methods of handling the fruit in the orchards and packing houses can be brought about. We know that the refrigerator cars in common use, when well iced, will maintain a uniform temperature of 35 to 40 degrees in a load of fruit indefinitely, that the fruit can ripen more fully on the trees if cooled before shipment, that the differences in maturity between the fruit in the top and bottom of the car are largely reduced, and that the fruit arrives with better quality, as the air of the car is drier and purer during the trip.

Therefore, I desire to ask you to consider the following questions:

1. Is it practical to construct warehouses at fruit shipping points, to be operated as a private or a transportation enterprise, at central packing houses or on large fruit ranches for the quick cooling of fruits, the probability being that the warehouses would be used a comparatively short period of the year unless they could be combined with a cold storage and ice-making business?

2. Is it practical, without interfering with the movement of traffic, to refrigerate fruit initially in cars by blowing cold air through the car from a refrigerating plant?

3. If the fruit could be loaded at a temperature of 35 to 40 degrees, could the freight-carrying capacity of the car be increased by closer piling and higher loading without endangering the condition of the fruit?

4. Could the capacity of the ice tanks be reduced, the temperature of the fruit still be maintained and the carrying capacity of the car be further increased under this method of treatment?

5. Does any method of maintaining a low temperature seem more practical than the use of ice?

These are some of the fundamental problems that the fruit grower has to face in his effort to build up the American fruit industry. They are not problems that can be settled offhand by the grower, the shipper, the car line, the railroad or the engineer. The interests of each are closely interwoven with the interests of the others. We submit the refrigerating problem for your consideration, with the hope that its importance may seem worthy of your attention.

DISCUSSION.

The President.—I would like to ask Mr. Powell if the shipping parishes in, for example, California, are sufficient in extent to fill a large-sized holding warehouse, or cooling warehouse, preparatory to shipment; that is, a warehouse, we will say, of two or three hundred thousand cubic feet capacity. If so, probably how many of such establishments could be used in the territory that he has in mind?

G. Harold Powell.—I cannot answer this question definitely. In the Riverside district, for example, about 6,000 carloads of citrus fruits are shipped. There are probably twenty packing houses in this district. One company forwards about 1,300 carloads of oranges and lemons throughout the year. The other houses ship from 250

to 600 carloads during the period of six months from December 1 to June 1, and there are probably 100 or more houses in California which ship from 50 to 400 carloads of fruit in a season.

None of the concerns operating packing houses have built cooling plants up to this time. The efficiency of such a plant will have to be determined first before one could say how many might make use of them.

Aside from the usefulness of a plant for cooling down fruit for shipment, there appears to be need of cold storage plants to equalize the distribution of the citrus crop—i. e., to extend the navel crop for a month or six weeks, or to extend the Valencia crop during October and November, and to help equalize the shipments during the season. The citrus business now represents about $27,000,000 gross, or 30,000 carloads of fruit. The distribution of the crop depends entirely on the supply of cars and the condition of the market. Oranges are not held in storage to any extent, though lemons are stored in common storage for several months. A warehousing system has been found essential in other lines of the fruit business as a link in the distribution of the crop where markets are subject to violent fluctuations in supply and demand.

R. L. Shipman.—It seems that cooling the fruit before it is put in cars is most feasible. I would like to ask Mr. Powell what is the usual fruit season.

G. Harold Powell.—In what part of the country?

R. L. Shipman.—In the West.

G. Harold Powell.—The citrus season begins about the first of November and extends to the first of the next October. It is practically a year-around business. The decays are most serious from the last of February to the first of June.

The deciduous fruit season begins in May with the cherries, and follows with apricots, plums and peaches throughout the summer months, and with large shipments of grapes throughout the fall.

There have been some attempts to cool fruit in cars. There is a large plant in Springfield, Mo., belonging to the United Fruit Company, which is equipped to cool thirty-six carloads of bananas at one time by blowing cold air through the cars. The banana is shipped under moderately warm temperatures. The fruit is cooled to about 50 degrees; a lower temperature blackens the bananas. Oranges and deciduous fruits ought to be cooled to about 35 to 40 degrees, as the ripening and decays are held back to a greater extent than in shipments under higher temperatures. If the fruit is cooled

to this temperature before shipping, an ordinary refrigerator car, if well iced and re-iced when needed, will maintain this temperature across the continent. Whether it is feasible to cool the orange by blowing cold air through the car is a question. We have done some experimental work along this line, especially with the Los Angeles Ice and Cold Storage Company. Through the co-operation of J. G. McKinney, its general manager, a member of your Society, several cars of oranges were cooled by blowing 800 to 1,200 cubic feet of air per minute at 32 degrees through the cars. Under these conditions it took about 40 hours to lower the temperature of the fruit in the center of the packages 25 degrees. A box of oranges weighs about 80 pounds. It is packed under pressure, the fruit is wrapped and it is very difficult to refrigerate the fruit quickly in the centre of the package. We question whether it would be feasible to attempt to cool fruit in refrigerator cars quickly under these conditions, though before a final conclusion could be reached a large amount of experimental work would need to be done.

With the Georgia peach, which is packed in an open carrier, the air circulates freely through the fruit, and as the peach is not wrapped, it is possible that the fruit could be cooled within a reasonable time in a car. The California peach is packed in 20-pound boxes, each fruit is wrapped, and we have found that it takes about twice as long to refrigerate the same quantity of fruit as it does the Georgia peach packed more open and unwrapped. The method of packing has an important influence on the practicability of cooling fruit quickly, either in cars or in warehouses. There are a number of engineering problems connected with this subject that need to be worked out carefully.

W. T. Robinson.—What is your judgment on the degree of humidity needed for the storage of fruit?

G. Harold Powell.—We have not experimented enough to form a judgment on that question.

W. T. Robinson.—Have you not reached a conclusion?

G. Harold Powell.—We have not. We think it one of the most important factors affecting the successful storage of fruit, but we have not had facilities at the Department of Agriculture to make careful tests along this line. We consider humidity and ventilation almost equal in importance with temperature. We know that a good deal of fruit keeps in good physical condition, but it comes out of storage with the aroma and flavor impaired. This is probably due to the impure air of the warehouse.

Louis Block.—Is that with or without ventilation?

G. Harold Powell.—I am unable to draw a satisfactory comparison, as we have not had enough experience to make a safe conclusion.

R. L. Shipman.—Do I understand that there is use for a storage warehouse in California for eight months? Might it not be possible to refrigerate the fruit before wrapping it with paper?

G. Harold Powell.—I should say that there would not be use for a storage warehouse for more than six months, and that the busiest season would extend from March 1 to June 1. I should think it would not be possible to refrigerate the fruit before wrapping, unless it could be wrapped in a cold temperature. When the fruit is taken from a cool room to a warm room it wets down, unless the humidity in the air is very slight. It would not be practical to handle the California labor in cold storage rooms. The fruit must be refrigerated after wrapping.

The President.—Could you give us any idea of what the traffic would stand; some terms, either for package or for grade?

G. Harold Powell.—I should say that a charge of from $20 to $30 per car, as a rough estimate, could be borne by the shipper. This charge would range from $1.50 to $2 a ton for handling and refrigeration. The losses in the orange and lemon business from decay range from $500,000 to $1,250,000 annually.

Harry M. Haven.—I would like to ask if the packages are separated in the cars by strips.

G. Harold Powell.—Yes. In the Georgia peach business the fruit is packed in carriers five tiers high. The vertical tiers are separated several inches and the horizontal layers are separated by an inch strip. In the citrus fruit business the vertical tiers are separated by two or three inches, and the horizontal layers from three-quarters of an inch to an inch. In the California deciduous fruit business every third tier is usually stripped for ventilation, and there is from two to three inches between the vertical tiers.

The President.—I would like to hear from Mr. Williams on the subject.

L. Williams.—Most of my information has to do with the banana. In the carrying of some 750,000 tons of fruit per annum, about one-quarter was handled in refrigeration. Some of the fruit in refrigeration goes to England and some of it comes here. The whole of our English trade is refrigerated.

We find that temperatures within limits are a minor consideration. Ventilation is the most important thing; that is, ventilation and pure air, together with suitable humidity.

We cool the fruit by blowing air through a brine pipe bunker before it enters the room where the fruit is stored, the brine in the bunker being about 25 degrees cooler than the air entering and about 15 degrees cooler than the air leaving. The banana is placed in the room at a temperature of from 90 to 100 degrees Fahr., according to the port of loading.

The bananas are stored in the vessel in bulk, and there is an air circulation right through the cargo. The average temperature of fruit going on board the vessel will be about 95 degrees.

If the master of a vessel has had sufficient experience he can, by the looks of his fruit on coming aboard, so regulate his temperature that he can land it with any required degree of ripeness that we instruct him on leaving the port of loading.

With natural ventilation, without any cooling at all, merely using the outside air, our average "ripes" are greater than with refrigeration. If the wind is against the vessel, there is good ventilation; if the wind is with the vessel, and blowing about the same speed as the vessel, there is more or less dead air. If the ship runs through a bank of fog it hastens the deterioration of the fruit.

The plant of the United Fruit Company, at Springfield, Mo., was erected under my guidance. I have no hesitation in saying that I believe that is the coming process for handling refrigerated goods in cars. You do away with the moisture you get by icing. We do not deal with low temperatures; 58 degrees is about the lowest we carry. From what I know of the cooler, I should say it would have about 87 per cent. of humidity. The air on the way to the car rises 3 or 4 degrees, owing to an arrangement of ducts and canvas tubes, which are uninsulated. That would raise its temperature without adding to its moisture. We draw the air through the car, the rise in temperature being about 15 degrees. We cool thirty-six cars of fruit about 26 degrees in twenty-four hours. The air, coming out of the car, is on an average about one degree colder than the fruit in the middle of the bulk in the car; that is to say, within a couple of feet of the grating opposite the door.

We took some of these cars and closed the inlet ventilators on top of them (they are not air-tight by any means), and slightly opened the outlet ventilators before starting them on their run to Kansas. We found the cars arrived in Kansas City, Mo., from Springfield with a rise of from 2 to 3 degrees.

I believe that if you were to take a car of oranges or berries and cool them down to what I would call their danger point, you could close that car up and run it 500 miles into another house, and

after cooling again send it off another 500 miles. You would get better results than by icing.

This house is equipped with heating apparatus to warm the cars in winter. We have had very good results during the past summer with this plant, and expect to get very good results from the heating apparatus this winter, more so than the cooling, as we have more fruit on the tracks waiting for a purchaser in the winter.

I understand from the officials of the "Frisco" Railroad Company that the management of the California Fruit Growers' Association is arranging to put its fruit through this house next year in some quantity, to give it a thorough trial, and negotiations are going on with our company to give them the right to use it for experimentation, and I think that the result of these experiments will be very beneficial.

This plant consists of a refrigerating machine, with an "American Linde" air cooler. I think that any form of an efficient cooler would give equally as good results. We have an 80-ton "Frick" refrigerating machine, which is capable of cooling forty cars of bananas through a range of 20 degrees in twenty-four hours, each car containing about 12 tons of fruit.

No. 6.

FURS AND FABRICS IN COLD STORAGE.

By Walter C. Reid, New York, N. Y.

(Associate Member of the Society.)

In the press reports of the launching of nearly every large cold storage enterprise in recent years the statement that "special rooms will be set apart for the storage of furs as a means of protecting them from damage from moths" is set forth as an attraction. That cold storage is the proper method for the storage of such goods has been abundantly proven, but there are very few commercial cold storage warehouses that are advantageously situated to secure much fur storage, unless it be from the manufacturer or wholesaler, from whom this class of goods is usually received in cases or bales. These warehouses are not usually situated in a locality attractive to the lady of the house, from whom the great volume of this business is received.

This business seems naturally to have fallen into the hands of the warehouseman who stores household goods, as his methods fit in with this class of storage. With him the furrier and department store keeper are now endeavoring to compete, with more or less success, and many of these, in their efforts to lend to the attractiveness of their warerooms, are lavishly devoting space to cold rooms, which they will realize later could be used to greater profit in their ordinary sales business. All business is becoming specialized and, no doubt, with time there will be special cold storage houses in large cities where furs and fabrics only will be stored, and where the fur man and the department store man will have their special rooms at a special wholesale rate, and the retail trade will have its rate for small lots of goods stored. An absolutely fireproof building is necessary for the storage of these goods, as their value is so great, considering the space occupied, that a high insurance would materially affect the revenue. The warehouseman handling this class of storage is expected to guarantee its safety against fire as well as moth.

The cold storage of furs and fabrics was first prominently brought to the attention of the cold storage warehouseman at a meeting of the American Warehousemen's Association held at Bos-

ton in the autumn of 1896. At this meeting Mr. Henshaw, of the Boston Society of Natural History, read a paper prepared by Dr. L. O. Howard, Chief of the Bureau of Entomology of the United States Department of Agriculture, presenting the results of the Department's investigations in this direction up to that time.

In the same year Albert M. Read, manager of the Storage Warehouse Department of the American Security and Trust Company, of Washington, D. C., gave the result of his experiments with cold storage as a moth preventive in the Washington *Financial Review* and also in *Ice and Refrigeration.* As a matter of fact, Dr. Howard's information was secured from the experiments of Mr. Read.

We can form but a slight idea of the amount of damage done each year by the moth worm and by the buffalo beetle, both to furs and fabrics, and there is no means of obtaining statistics. That it amounts to millions of dollars will, I think, not be questioned. In a pamphlet recently issued by the Department of Agriculture, entitled "The Annual Loss Occasioned by Destructive Insects in the United States," C. L. Marlatt states: "The various . . . weevils and beetles, flour moths, and other insect pests which depredate on stored grains, frequently cause great losses, and an estimated injury of 5 per cent. is a reasonable and probably minimum figure. Computing this percentage, therefore, on the valuation of the cereal products for 1904, we have indicated an annual loss of $100,000,000.

"Animal products are attacked by larder beetles, ham beetles, etc.; fruits by various fruit and vinegar flies, and the woolens of the household furnishings by carpet beetles, clothes moths, silver fish, etc."

Chemical preparations cannot be relied on as moth destroyers, or if they will destroy these pests they are apt to injure the fabric. Cold storage offers absolute safety, for, given a temperature so low that the moth egg will not hatch, the destructive little worm cannot develop.

Previous to 1896 furs and woolens were stored in packages in commercial cold storage warehouses. Trunks of clothing were received. Single garments were taken and suspended in cold rooms with other goods, but no special attempt was made to encourage this class of storage, unless we except the efforts of the Terminal Warehouse Company, of New York, N. Y. In the early days of that enterprise, Morland Conklin, the superintendent of the cold storage department, who had been a furrier, set aside several rooms

for the storage of furs and fabrics, and advertised the business to some extent; but this warehouse, being located on the water front, was not situated in an ideal neighborhood to attract this business, and it was afterward abandoned.

As previously stated, the goods received are often of great value, and an expert conversant with the value and condition of such goods may be employed to advantage. The goods are usually undervalued to secure a low rate of storage, but to discover defects in the condition often requires the eyes of an expert, and should he fail to note the defects on the receipt of goods the warehouseman may have an opportunity to stand for an interesting damage claim.

To Albert M. Read we are indebted for the present development of this business. His company erected two rooms, 20x60 feet each, one above the other, in its fireproof warehouses and insulated them with mineral wool. Brine pipes were strung along the walls and a 10-ton compressor was installed to supply the refrigeration. In addition to the two large rooms, Mr. Read had built for experimental purposes a thoroughly insulated small room fitted with brine pipes, divided into several sections by stop cocks, so that the temperature could be readily controlled to a reasonable degree, and with the assistance of Dr. Howard, who furnished the eggs and larvæ of the moth and buffalo beetle and of some other insects, Mr. Read began his experiments, which extended over a period of two years. He commenced at first with a temperature of from 20 to 25 degrees F., and progressed upward till temperatures of from 50 to 55 degrees F. were reached. As the result of his experiments Mr. Read reported as follows:

"It is probable that the eggs of the moth and the beetle require a temperature somewhat higher than 55 degrees for hatching. I say probably, because, owing to the difficulty of obtaining the eggs, my experiments on them have not been sufficiently numerous to allow of positive conclusions, although those that have been made point strongly to the possibility stated.

"The larval condition is the one in which all the damage to fabrics is done by the insects in question. In passing from the egg through this condition to the perfected insect the fibre of the wool, fur, etc., is eaten by the larvæ of both the moth and the beetle for the grease and animal juices in it, these constituting the principal source of food, and by the larva of the moth for material out of which to spin the web that constitutes a large proportion of the cocoon used for its protection. In the larval state it was found that any temperature lower than 45 degrees was sufficient to keep the insect from

doing damage to the fabric, although at that temperature, and at a temperature as low as 42 degrees, there was slow and sluggish movement of the animal. At temperatures below 40 degrees movement was suspended, and the larva became dormant. At temperatures above 45 degrees the movements of the larva became active, and it began to work upon the fabric, the amount of this work and the quickness of movement increasing with each degree of temperature up to 55 degrees, when the normal condition of activity appeared to be reached.

"The miller and beetle, when subjected to temperatures below 32 degrees, were soon killed, as they were also after a longer time at all temperatures between that and 40 degrees. At temperatures between 32 and 40 degrees, however, when the insects were placed in the centre of a roll of heavy woolen rugs, they appeared to enjoy an immunity from death for several weeks, although during this period they were entirely dormant.

"It will be seen from the above that the investigations made have quite conclusively proven that cold storage rooms for the preservation of furs and fabrics from the ravages of moth and beetle may be kept at a temperature as high as 40 degrees F. with perfect safety, so far as these insects are concerned. There may, in some plants, however, be trouble from the drip from the cooling pipes of the storage room at this temperature, which will, of course, be very objectionable, and should be obviated by a slight lowering of the temperature of the room. We have run our rooms at temperatures varying from 35 to 40 degrees without trouble in this regard.

"In the course of the investigation some matters of interest in connection with the effect of cold upon these insects came to my notice. As these may prove of value in the future I will state them in a few words. It was found that the larvæ of both the moth and the beetle had the power of resisting temperatures as low as 18 degrees F. for a long period without apparent harm, and that they came out of the dormant condition superinduced by the low temperature in the same physical condition as when they entered it, and apparently took up their natural avocation at the precise point where it was interrupted. When these larvæ were alternately exposed to low and higher degrees of temperature, so that they passed from the dormant to the active condition and back again several times in succession, their power of resistance was considerably lessened, and they died much sooner than when kept dormant in a low temperature continuously. This would indicate that a winter during which short periods of cold are followed by similar periods of

warm weather would be followed by a summer of decreased insect life."

While Mr. Read was experimenting with the scientific side he was having success with the commercial side. His rooms became popular and were soon filled. Garments as received were carefully brushed and hung on shoulders suspended from rods; rugs were rolled on poles; special boxes were made which were rented out to patrons, who filled these at home with furs and clothing and sent them to the warehouse.

The business of the American Security and Trust Company has continued to grow until it now readily fills more than triple the capacity of the original rooms. They have removed the brine pipes from the rooms and substituted the indirect system, forcing the cold air through ducts to the various rooms. They have made and are constantly making other improvements that keep this plant at all times thoroughly up to date.

Some two years later, or in 1897, the company with which the author of this paper is connected became interested in this subject. They had a suitable building and a large clientage of wealthy people already established. It had been a hobby with the chairman of the executive committee that no woodwork of any kind should be a part of the building. Even the window sash are of iron. It, therefore, became necessary to prepare a scheme of insulation without the use of wood. This was successfully accomplished, with the exception of the doors, which were covered with kalamein iron.

Two rooms, 21x75 feet, one above the other, surrounded by brick walls, were selected. The floors were covered with asphalt over concrete filled in over brick arches supported by steel beams. All walls and ceilings were coated with pitch and covered with insulating paper, and an interior wall, separated 4 inches from the supporting walls, was erected and the intervening space was filled with mineral wool. From the ceiling of the floor below the lower room a false ceiling was suspended, made of specially prepared plaster blocks, being held in place by light ⊥ irons and filled in above with mineral wool. The ceiling of the upper room was similarly constructed. Coils of piping were suspended along the sides of these rooms. A 15-ton compression machine was used in the expectation that the business might require additional space, and this machine did later successfully cool two additional rooms of a similar size, and in the summer of 1904, during repairs to the present 35-ton compressor, for several days, when there was little or no access to the rooms, held the temperature down on eight such rooms.

This company, now probably the largest devoted to this class of storage, has been successful from the start. To the two original rooms two others were soon added, insulated in the same manner, but with a different arrangement of the brine pipes. It was early found that the drip from the pipes along the sidewalls sputtered onto goods placed too near them, and the pipes were accordingly banked over a central passageway with a large drip pan underneath. Three additional floors were added and these were lined with sheet cork covered with a special cement plaster. The piping in these was arranged in the same manner. There was but one other floor available in the building, and this was subsequently taken, so that now our entire building, nine stories in height, the first story being a general receiving room, is devoted to this business. The danger from damage by leaks in brine pipes was ever in mind, and as our Washington friends, Mr. Read's company, had changed theirs to an indirect system, we were inclined to follow their example, but finally decided on the construction of a special bunker room, with ducts in the room and with electric fans to promote the proper circulation. This has worked satisfactorily on one floor. As the old-time coils are wearing out the indirect system is being established.

This past year the piping has been removed from the two original rooms, a bunker room has been erected at one end of the upper room, holes cut through the floor at each end of the room, fitted with fireproof doors, held open by fusible fasteners, that in the event of fire will permit of the doors falling, and thus isolating one room from the other. The cold air from the bunker room passes down through the openings to the floor below and passes back through the holes at the other end to the upper floor and back to the bunker room. No fans are used in these rooms.

The warehouse as originally constructed contained on two of the floors rooms of about 1,000 cubic feet capacity, with 4-inch brick walls and iron doors, five on each side of a central passageway. When these floors were taken for cold storage, galvanized wire doors were substituted for the sheet iron doors, and the brickwork for about 2 feet from the ceiling was removed from the front of each room alongside the bank of brine pipes so as to promote circulation. These rooms are rented to furriers, who place in them such garments, etc., as they wish, no receipts being given them and they retaining possession of the keys.

Since these two plants were established many others have been erected in different parts of the country and have, it is believed, been uniformly successful.

One not in touch with the business can have no idea of the vast wealth contained in these goods. We have a number of customers owning from ten to forty sets of furs. We have stored a set of Russian sables valued at $35,000, several cases of tapestries valued at $75,000, a set of tapestry furniture that was invoiced from abroad at a value of $35,000, and we have many fur garments valued at $8,000 to $10,000.

In handling goods of such value when their safety is guaranteed a percentage charge is made for valuation in addition to a charge for space. The storage rate for space ranges from 4 to 8 cents per cubic foot per month, according to the probable length of time goods are likely to be stored and the nature of the goods.

Single fur garments and rugs are stored by the season of nine months. Of course local conditions have some effect on the charge for furs, it being advisable not to exceed the charge made by the local furrier for storing, under the old method.

The furrier usually makes no charge for sending for and delivering fur garments, and this means the added expense of a wagon service.

In some cities the local furrier has arranged to handle this class of storage, hiring rooms from the commercial cold storage men. It is believed this will be found more profitable for him than the maintenance of a small plant on the furrier's own premises.

DISCUSSION.

The President.—I would like to ask Mr. Reid one question, and I do not know whether it is of any great importance. There is an idea that I have heard frequently expressed, that in the storage of furs the low temperature in which they were kept improves the furs; that is, they came out in better condition, as to brilliancy of appearance, than if they had been treated with some chemical substance. I would like to know if there is anything in that?

Walter C. Reid.—You are quite correct, Mr. President. By the old-fashioned method, using chemicals and beating, it has been necessary for furriers to do what they call "glazing." They use some preparation on the fur to give it a glossy appearance. With cold storage that is not necessary at all. We have found, especially with cheap furs—bearskin coats, for instance—that garments received in poor condition go out with as fine an appearance as anybody could desire. The hair is stiffened up and presents a glossy appearance

No. 7.

THE EVAPORATOR AND ITS USE IN THE MANUFACTURE OF CAN ICE.

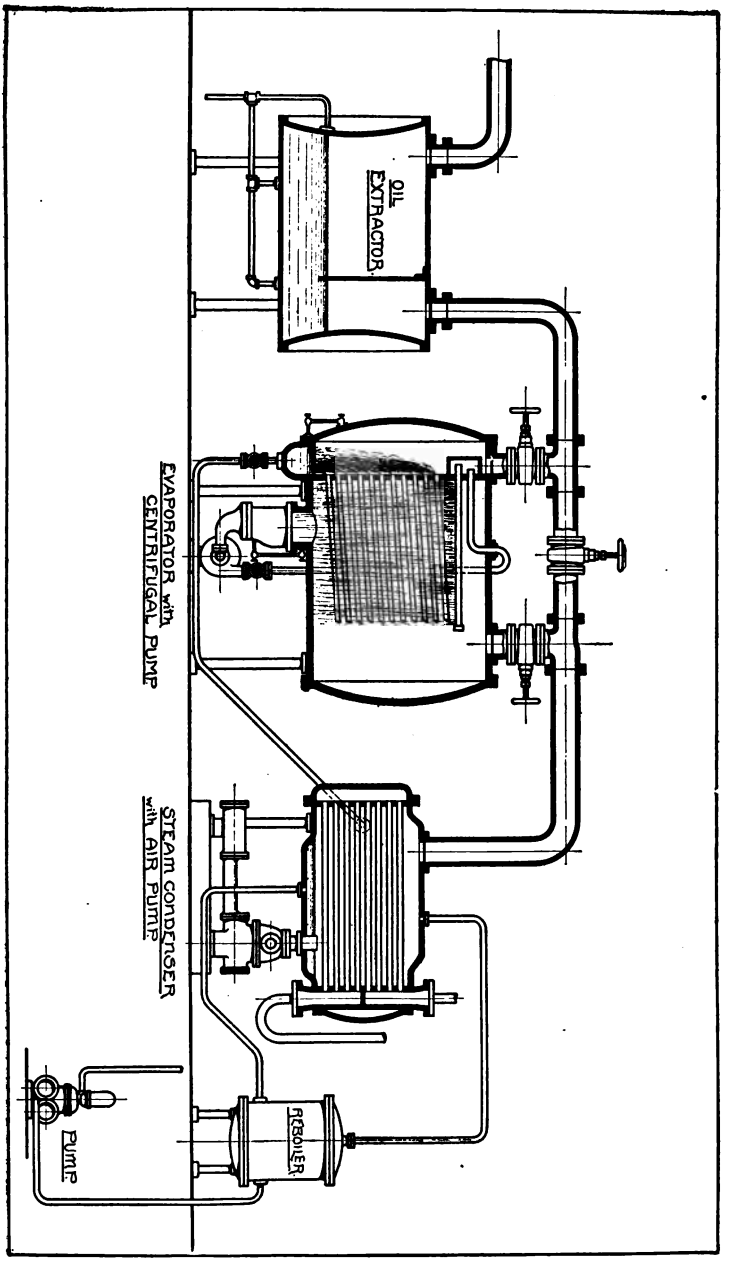
By Louis Block, New York, N. Y.

(Member of the Society.)

Soon after the development of the can ice manufacturing industry, the fact was recognized that the refrigerating machine itself had very little to do with economical results to be obtained in an ice-making plant. As long as the engine which drove the compressors was not positively wasteful, as long as the exhaust of this engine, of the pumps and other auxiliary machinery did not, when condensed, produce a larger quantity of distilled water than the machine could freeze into ice, we were quite satisfied. We soon knew that the economy of ice production depended entirely upon the efficiency of the steam boiler. If the boiler evaporates 8 pounds of water per pound of coal, and we lose, as we always do, 25 per cent. by steam cylinder condensation, condensation in exhaust pipe and loss by reboiling and skimming, we may hope to produce 6 tons of ice per ton of coal, and I may say here that very few plants show such good economical results for a whole season.

The knowledge that we could do work equal to the melting of 18 tons of ice per ton of coal, and only manufacture 6 tons of ice for the same quantity of fuel, led to efforts to improve the economical results of ice-making plants, and the use of compound condensing engines in connection with an evaporator in which the exhaust steam is used to produce additional distilled water was resorted to.

In many ice-making plants where evaporators are in operation the "Lillie" evaporator has been used. It consists of a cast-iron shell, and is provided with copper tubes. Near one end is the tube head which divides the evaporator into two parts; one is called the steam space, the other the vapor space. One end of the copper tubes is expanded in the tube head, the other end of the tubes is closed, but the closed ends are each provided with a very small air vent hole. Under the evaporator a centrifugal pump is placed which serves to circulate the water over the tubes, a float in the float box keeps the water always at a predetermined level, and the glass gauge on the float box indicates the water level.



THE "LILLIE" EVAPORATOR.

The exhaust steam from the low pressure cylinder, usually under a vacuum of 18 inches and a temperature of 169 degrees Fahr., enters the steam space of the evaporator and thence the copper tubes. The water which is showered over the tubes in the vapor space of the apparatus evaporates, owing to the lower vacuum, 25 or 26 inches, which, by means of the condenser and air pump, is maintained in this space. The temperature of vapor under a vacuum of 26 inches is 126 degrees, and the difference between 126 and 169 degrees is quite sufficient to produce boiling and consequently evaporation. The steam which enters the copper tubes is condensed, drops to the bottom of the steam space, and from there is periodically discharged into the steam condenser.

The vapor is, of course, pure, clean and free from any odor, owing to the fact that it is distilled at a low temperature. The steam, however, which has done its work in both the high and low pressure cylinders of the engine, contains all the impurities which such steam is subject to in any ice plant, viz., oil, oxide of iron and free ammonia. In order to free it from the oil and oxide of iron it must be washed or passed through a coke scrubber in the usual way, except that in this case the oil extractor or coke scrubber must be operated under the same vacuum which is maintained in the steam space of the evaporator.

The vapor after it leaves the evaporator enters the top of the steam condenser; the air pump, by taking away the air and most of the ammoniacal gases, which have not yet been reabsorbed by the distilled water, maintains a vacuum of from 25 to 26 inches.

From the condenser the distilled water flows by gravity to the vacuum reboiler, a vessel preferably made of cast iron and provided with bull's-eye glasses opposite each other so that the water in it may be plainly seen. A steam coil at the bottom of the reboiler supplies the heat necessary to maintain a lively ebullition of the water, and the resulting steam travels through an equalizing pipe back to the condenser. You will see that no steam or vapor is wasted, and you will observe that it requires but little steam to bring about a boiling temperature in the reboiler. The condensed water enters it under a vacuum of 26 inches and a temperature of 120 degrees, and needs only to be heated to 126 degrees in order to reach the boiling point. In the reboiler of the ordinary ice plant the condensed water reaches the reboiler at a temperature of from 125 to 130 degrees. It must be heated to 212 degrees before it boils, and the resulting vapor passes through the vapor pipe out through the

roof and is lost. It does not require higher mathematics to arrive at the saving effected by this simple device.

A pump, the speed of which is regulated by a float in the reboiler, transfers the distilled water, now as pure as is possibly obtainable in an ice plant, to the so-called skimming tank, and thence it takes its usual course.

I have described the "Lillie" evaporator because that is the one often used, and I consider it the best adapted for the purpose. With it seven-eighths of a pound of vapor can be produced for every pound of steam which enters the steam space. To produce 100 tons of distilled water would require 55 tons of exhaust steam; but in order to have that quantity enter the evaporator 73 or 74 tons must have entered the high-pressure steam cylinder, and this determines the economy of the plant.

There is only one place where loss of heat takes place which cannot be prevented, and that is at the blow-off cock of the evaporator. From time to time some of the water contained in the vapor space must be blown off, the same as a boiler must periodically be blown down, for the purpose of preventing evaporation to dryness and excessive accumulation of scale on the evaporator tubes. In spite of this loss, if the apparatus is correctly proportioned, 10 tons of distilled water can ice can be made per ton of coal if the latter evaporates 8 tons of water under the working pressure in the boiler per ton of coal. We have at a test made more than 11 tons of ice per ton of coal.

In such a plant as I have described the exhaust steam from auxiliary machinery and pumps is used for heating the boiler feed water, and the water for the evaporator, if it is suitable, is heated by using it for cooling the distilled water. If it is too hard to be used in the evaporator, that is, if it contains more than 4 grains of lime or magnesia in solution per gallon, it must be softened.

The operation of such a plant is extremely simple, and it is not difficult for the operating engineer to understand it; in fact, it requires no more attention than an ice plant with compressors driven by a compound condensing steam engine.

DISCUSSION.

Thomas Shipley.—Do you allow the gas to go back into the condenser?

Louis Block.—You do not allow the gas to go back into the condenser; it is taken off by the air pump.

Thomas Shipley.—Do you boil the water?

Louis Block.—We boil the water in order to get the air, which has been reabsorbed, out of it again. The reboiler is mostly for the purpose of getting rid of that air which has been reabsorbed, and the reabsorption of air is principally due to the fact that we allow the water in our condenser to get down too low in temperature. If we would keep it at 135 degrees we would not reabsorb air, but we do not pay any attention to it, and during the cooling process it reabsorbs any gas or air that may be in the condenser. The vapor and the air are separate before condensation, but during condensation and cooling some air and gases are reabsorbed.

Thomas Shipley.—In my experience, whenever we used a vacuum reboiler, we arranged to discharge the gas into the atmosphere with a dry vacuum pump.

Louis Block.—I think you will do quite as well if you do it in accordance with the diagram.

Thomas Shipley.—It seems to me you are driving out impurities at one end and then bringing them back again.

Louis Block.—Your suggestion requires a regular air pump with very little clearance, while I can use the ordinary water-sealed vacuum pump.

Edgar Penney.—Do I understand that you are simply pumping those impurities back and forward and all accumulations due to the incoming water are threshed back and forward, constantly accumulating until they reach a point where the apparatus must be stopped and cleaned?

Louis Block.—It is not shown in the figure, but there is a nozzle and a valve, and you open this valve every six hours for a few minutes, just the same as you would open a blow-off on a boiler. Then the pump will throw the water out, and that is done sufficiently often to prevent evaporation to dryness. If we did not do this we would evaporate every bit of water to dryness.

Edgar Penney.—Practically the only break you have in the system from the time it leaves the pump is this temporary blow-out?

Louis Block.—That is all, but it is fresh water that is allowed to come in.

Edgar Penney.—You are continually feeding that apparatus with steam that comes practically from the boiler without any break for eliminating certain properties that generally pass off in a reboiler.

Louis Block.—Any air or gases would pass off and be carried back to the condenser; the air pump will take them away.

Edgar Penney.—Where?

Louis Block.—They are discharged into the atmosphere.

Edgar Penney.—Then I understand you have a break in the system where the gases are pumped out all the time into the atmosphere?

Louis Block.—Oh, yes.

Albert A. Cary.—I was not here at the opening of this paper. Concerning the oil extractor, I suppose that it is similar to a filter?

Louis Block.—No, it is not. The extractor simply depends upon the impurities being thrown down upon the surface of the water, and this water flows off through the drain pipe. The drain must be located at such a height that the water will run off into a sealed tank, which is 25 or 30 feet below.

Albert A. Cary.—I have had considerable experience with oil in exhaust steam, and find it exists there in three different forms: First, in solid little globules of oil suspended in the steam; second, small particles of water, condensed from the steam, with their outer surfaces coated with oil; and third, a vapor of the oil itself which accompanies the steam.

Louis Block.—Would the oil vapor in contact with the water still be vapor?

Albert A. Cary.—Such tests as I have made would incline me to believe that it would, unless the vapor was sufficiently cooled to condense it, which cooling may be accomplished on a water surface.

Louis Block.—The separator is simpler, because it is more easily cleaned than the coke filter. The coke picks up the oil by having it impinge against such large surfaces that it holds it, and you will find if you clean your coke filter that the coke is thoroughly soaked with oil at the end of the season. The device shown in the figure does it by contact of steam with the water. You might do still better by having the exhaust steam enter below the surface of the water, and we have used such apparatus. Either one does it sufficiently good for ice-making purposes.

Some of the grease is always found in the skimmer, and it is allowed to overflow in the usual manner. An ordinary marine air pump takes the water from the reboiler, to which it flows by gravity, at the same rate at which the water is produced. I have simply illustrated this oil extractor so as to illustrate something which is the same as in any other ice plant. Whatever apparatus is put there must be built strong enough so that it will not collapse.

Edgar Penney.—Then I understand that the practical benefit gained by the use of such an apparatus would be about 25 per cent.?

Louis Block.—You can make 10 tons of ice per ton of coal, where you now make 6.

Edgar Penney.—That is very much more. I suppose you use compound condensing engines of the most economical type?

Louis Block.—That is the idea, to use an economical engine and still make can ice. I consider can ice preferable to plate ice, for the reason that its manufacture can be continuous and allows you to keep the men employed at the same thing all the time. I have always called the manufacturing of plate ice plate ice-making. Plate ice has got to be harvested at some time in the day; it takes four or five hours.

Edgar Penney.—I should not think that the interval of time in harvesting the product would make any difference. It is a distinction without a difference. The machine works right along, produces ice right along, whether the men are watching the process or busily engaged in yanking ice out of cans.

Louis Block.—I think it is better for the men to keep them busy steadily.

Edgar Penney.—In a well arranged plate plant you do not need so many men as in a can plant, as you do not have so many loafing. That saving would be very interesting, and it seems to me that along those lines of reducing labor only can there be hope for a can plant to compete in economy of production with a plate plant.

Louis Block.—Yes; and it is a little cheaper. It will only increase the cost of an ordinary can plant from 15 to 20 per cent.

Edgar Penney.—That would be all the apparatus you would employ, doing away with the filtering?

Louis Block.—No; from the pump it goes to the skimming tank, and afterward you do all that you do in the ordinary ice plant. You cool the water and deodorize it.

L. Howard Jenks.—I would like to ask Mr. Block if there is any difference between the condensed steam from the exhaust of a simple engine and that of a compound condensing engine, such as would be used for his plant. Is it not a fact that the oil and water come out as an emulsion?

Louis Block.—Why should they come out as an emulsion any more than with a high pressure engine? The only oil and water which I have ever seen run away from the exhaust of either this or any other engine looked milky, and you might call them an emulsion. I think that is simply a mechanical mixture, but there is absolutely no difference between the discharge from a compound engine and the exhaust from a high pressure engine.

L. Howard Jenks.—I would say that a bottle containing condensed steam from a compound condensing plant stood on my desk for a year without the separation of the oil.

Louis Block.—You must have had rape oil for lubricating the cylinder.

L. Howard Jenks.—No; it was apparently a true emulsion.

Louis Block.—The ordinary mineral oil will not form an emulsion, but if you mix rape oil with it then it will form an emulsion.

Edgar Penney.—To interject a remark which possibly may not be relevant, but touching upon the oil question, it seems to me that the bugbear of oil in a can plant has been overworked—worked to death. Probably a 100-ton ice-making plant might use a gallon of oil.

Louis Block.—Perhaps not as much as that.

Edgar Penney.—Perhaps not as much as that; perhaps a quart. But imagine a quart of oil distributed in 125 tons of water, and take into account the freezing point of the oil and the freezing point of water, and try to get oil and water to mix under those conditions. The oil would flow to the top of the can and be carried off, so that this elimination of oil "cuts very little ice." No oil is used in an absorption machine and yet every smell, odor and disease that trouble can plants of the compression system you find in the absorption.

Louis Block.—Quite right; besides I suppose between 60 and 75 per cent. of the oil is taken away before it reaches the oil extractor.

Edgar Penney.—I have made experiments by taking oil of different grades and qualities. I put in quite a liberal quantity to see if I could find any trace of it. Invariably it went to the top. If there were any impurities in the oil they went to the bottom; but the oil was simply eliminated. It flowed to the top and was washed off as soon as it went into the releasing apparatus. I think the oil cuts very little figure.

Albert A. Cary.—I do not wish to criticise Mr. Penney's experiments, but after an extended experience with oil held in condensed steam I find there is a great difference between *free* oil in the water and such oil as this gentleman spoke of a few moments ago, which is held in the water in an emulsified form. The oil put in by Mr. Penney was undoubtedly an emulsion of oil and water. The nature of an emulsion of oil and water does not seem to be generally understood, and I had little conception of the peculiar relation between these two liquids existing in this condition until I

had occasion to study the matter very carefully, and then a microscopic examination gave me the information I sought for. By passing a light upward through the glass miscroscope slide containing the emulsion I found an almost innumerable number of separated globules of water, each one being coated with an extremely thin skin of oil, beautifully iridescent in the rays of polarized light. I expect to say more about this subject in connection with one of the topical discussions to-morrow, but will add now that the removal of oil from water when in an emulsified condition has not been a simple problem, and I have found that the oily taste in ice is chiefly due to such emulsions being formed.

Louis Block.—It tasted oily? How does oil taste?

Albert A. Cary.—The taste of lubricating oil is not altogether dissimilar to that which its odor would indicate. In a case I recall, where can ice had a flavor similar to that just described, when tested in the laboratory it showed a trace of oil contained in its resulting water.

The President.—I have noticed, Mr. Block, on the upper print you have illustrated not only the double effect, which I suppose this might be called, or single effect, considered as it is—or a double effect, if you consider the boiler as a part of the effect—but also a diagram showing a triple and a quadruple effect, and I wish to ask if you have found any use for anything further than the double effect that you have exhibited there?

Louis Block.—No; I have tried a multiple effect, but it is not necessary, because a single effect gives you the necessary quantity of water with the highest possible vacuum that you could obtain, as high as 21 inches during cool weather, but the vacuum during the summer season may be maintained at 18 inches. That is as good as you can expect to do. With a double effect you get more water, but as you do not need any more water the single effect is good enough, and is really the best thing. It gives you the best vacuum in the low-pressure cylinder.

Albert A. Cary.—This system, as I understand it, practically limits your vacuum at the low-pressure cylinder to 18 inches?

Louis Block.—Yes, except as I say in cool weather or late in the fall we have run as high as 21 inches.

R. L. Shipman.—This form of vaporizer gets a good deal of work out of the steam before it goes into the vaporizer, and the final amount of heat which could not be used by the engine can be used by the vaporizer, and this ought to be more efficient than the live steam vaporizer.

Louis Block.—Yes; it figures a little more economically, besides it appeals more to the user.

R. L. Shipman.—One pound of steam in that boiler, exhaust steam, will evaporate nearly one pound of water?

Louis Block.—About seven-eighths. There is some loss by radiation of heat, of course. The higher the temperature of water which you allow to flow in the greater your evaporation will be. You can produce more vapor per pound of steam than you could otherwise.

R. L. Shipman.—Will the ordinary quantity of condensing water be sufficient to supply the evaporator?

Louis Block.—It is a matter of easy figuring. If you shower more water over the condensers than is necessary to produce seven-sixteenths of all the water which you require in your ice cans, then that water will be quite sufficient, and you usually shower more water over your condenser than seven-sixteenths of the quantity of distilled water that you are making. The vacuum regulates itself. Start with 26 inches in the steam condenser and you will get 18 inches in the low-pressure cylinder.

No. 8.

THE CARBONIC ACID REFRIGERATING MACHINE.

By J. C. Goosmann, Chicago, Ill.

(Member of the Society.)

The choice of a refrigerating medium is governed by its boiling point at ordinary pressures; the latent heat of vaporization per pound; the number of cubic feet of vapor that must be compressed to produce a certain refrigerating effect, or, in other words, the size of the compressor necessary; the pressure required to produce liquefaction of the gas at certain temperatures, and the specific heat of the liquid.

In order that the above characteristics of a refrigerating medium may be fully understood it is necessary to become familiar with the changes which take place within the same during its practical application, the first of which is that of temperature.

The object of refrigeration is the reduction in the temperature of a solid, liquid or gaseous body below that of its surroundings, and the maintenance of such lower temperature against the natural influences tending to restore the original equal condition, or, in other words, the tendency of a colder body to absorb heat from its surroundings until equal temperatures are established.

All gases have weight, some—for instance, carbonic acid—being much heavier than air; others, such as hydrogen, being much lighter. Each gas has a critical point on the temperature scale above which it cannot be liquefied; below this point it liquefies as soon as the necessary pressure is applied. When a gas is subjected to pressure at temperatures within which it can be liquefied, its volume decreases from that of its gaseous form until, upon continually increasing the pressure, it reaches its volume as a liquid. At the point of condensation the pressure, volume and temperature depend one upon the other and the substance passes from the gaseous into the liquid state.

The critical data of various gases, together with their boiling and freezing temperatures, are contained in Table I.

TABLE I.

CRITICAL DATA, BOILING POINTS AND FREEZING TEMPERATURES OF VARIOUS GASES.

SUBSTANCE.	Boiling Point at Atmospheric Pressure in Degrees Fahr.	Freezing Point at Atmospheric Pressure in Degrees Fahr.	Critical Temperatures in Degrees Fahrenheit.	Critical Pressure in Atmospheres (14.7 lbs. = 1 atm.).	Critical Volume in Cubic Feet Per Pound.
Water—H_2O	+212	+ 32	+657	205	0.037
Alcohol—C_2H_6O	+172	—148	+423	67	0.114
Sulphur dioxide—SO_2	— 14	—105	+313	81	....
Ammonia—NH_3	— 27.4	—106.6	+266	115	0.048
Carbonic acid—CO_2	—110	—110	+ 88	75	0.035
Oxygen—O	—296	—269	—180	52	....
Atmospheric air	—312	....	—220	39	....
Nitrogen—N	—317	—353	—231	36	....
Hydrogen—H	—400	....	—382	21	0.037

The temperatures given in the column "Critical Temperatures in Degrees Fahrenheit" are those above which no liquefaction will take place at any pressure, and after the significance of that temperature had been fully understood it became possible to liquefy the most refractory gases by pressure when cooled down below their critical temperature.

It also explains the great difficulty of liquefying air. Its critical temperature is so low that it requires a special intensifying apparatus, devised by Professor Linde, to cool it sufficiently before it can be liquefied.

Hydrogen requires the low temperature of —382 degrees F. before it liquefies. Professor Dewar succeeded in producing liquid hydrogen in 1898.

Heat and Work.—Heat as it appears ordinarily is regarded as a natural phenomenon. Another form of heat is produced during chemical combinations, more especially during combustion. The third source of heat appears when mechanical energy is expended in the form of friction, percussion or pressure.

The relation between heat and work was established in 1842 by Mayer and Joule, which led to the recognition of the first law of thermodynamics, i. e., that heat and work are mutually convertible at the rate of 778 foot-pounds per every unit of heat.

When this law is practically applied to 1 cubic foot of air in-

closed in a cylinder having a movable piston, it will be found that for each degree increase in its temperature there will be an increase of 1-493 of its volume, and the piston will be moved a corresponding distance.

The law holds good so far as the conversion of work into heat is concerned; it must be modified, however, when the condition is reversed, as in this case only a certain portion of the heat can be converted into work; the balance remains unconverted as heat of a lower temperature, and cannot be transferred to a higher temperature without the expenditure of some external energy—second law of thermodynamics.

The steam engine is one of the most economical means of turning heat into work. In doing work steam of a high temperature expands in the steam cylinder; after performing work it enters a condenser where the temperature is much lower; the heat carried over into the condenser represents the unconverted balance of the whole.

In the refrigerating machine the process is exactly opposite. Gas of a low temperature enters it and mechanical energy is converted into heat, changing the volume as well as the pressure of the gas. When the heat so imparted to the gas is removed liquefaction takes place, during which the latent as well as the specific heat of the gas is also absorbed. This liquid can then be made to evaporate by removing the pressure which keeps its volume concentrated, and it immediately boils at a low temperature, turning again into a gas. Before it can boil, however, it must absorb heat, and as the temperature of the substance surrounding it is much higher than its boiling point, it abstracts the heat from its surroundings.

The refrigerating industry requires the service of gases—refrigerating mediums or agents—that have the faculty of absorbing large quantities of heat at low temperatures, which heat can subsequently be removed from the gas at high temperatures. Water is used to remove the heat previously absorbed after the volume, pressure and temperature of the gas have been changed by work; it follows, therefore, that the critical temperature of the gas which is used must be higher than the temperature of ordinary cooling water. In addition, it is of importance that the pressure required to liquefy the gas does not exceed practical limits.

Among the gases suitable as refrigerating agents carbonic acid, ammonia and sulphur dioxide have been found to conform best to the requirements as set forth. The qualities of these three refrigerants are enumerated in Table II.

TABLE II.

QUALITIES OF CARBONIC ACID, SULPHUR DIOXIDE AND AMMONIA AS REFRIGERATING AGENTS.

SUBSTANCE.	Abs. Pressure in Pounds per sq. inch at 0° F.	Heat of Vaporization per pound at 0° F. (old data).	Heat of Vaporization per pound at 0° F. (Lorenz).	Volume in cu. ft. per pound at 0° F. (old data).	Volume in cu. ft. per pound at 0° F. (Lorenz, Stetefeld).	Specific Heat of the Liquid (old data).	Specific Heat of the Liquid (Mollier, Lorenz, Stetefeld).	Heat of Vaporization per cu. ft. (old data).	Heat of Vaporization per cu. ft. at 14° F. (Stetefeld).	Loss in per cent. Due to Cooling the Liquid (Lorenz, Stetefeld).	Loss Due to Clearance, Friction and Leakage (Stetefeld).	Useful Heat of Vapor per cu. ft. compr. vol. (Lorenz, Stetefeld).	Volume in cu. ft. per pound at 14° F. (Stetefeld).	Comparative Practical Efficiency (Lorenz, Stetefeld).
Carbonic acid—CO_2.....	310	123.2	115	0.27	0.3	1.00	0.79	444.7	483.5	17	19	400	0.44	1
Sulphur dioxide—SO_2...	10	171.2	161	7.35	7.4	.41	0.277	23.3	32	5	43	28	5.3	1
Ammonia—NH_3.....	30	555.5	588	9.10	9.5	1.02	1.153	61.7	83.7	4.5	42	80	7.0	1

Any one of the above substances has a boiling point which is much below normal temperatures. Carbonic acid, for instance, boils at 110 degrees below zero at atmospheric pressure. Before it can be changed from a gas into a liquid it must be robbed of its latent heat; it follows that if its latent heat is restored to it, it will begin to boil and again become a gas. In boiling it will absorb heat from any substance that may be near it, and on being compressed the gas gives up the heat so absorbed to the cooling water and again becomes a liquid.

The compression system of refrigeration, using the latent heat of vaporization of the substances named, consists of three parts:

1. A compressor which reduces the volume of the gas and increases its temperature by changing work into heat.

2. A condenser in which the heat imparted to the gas is given up to cooling water, thereby liquefying it.

3. An evaporator in which the liquid is made to boil, absorbing heat from the substance surrounding it, and changing the liquid into a gaseous condition.

It has been explained that each of these three refrigerants requires power to compress it before liquefaction, so that the question of power consumed in the operation of one or the other system needs to be duly considered. Manufacturers of the various types have made the claim that there is considerable disparity between the three systems concerning this point, each maker of a special type claiming that the advantage is with the particular machine and system made in his establishment.

Comparative Efficiency of Refrigerating Machines.—Investigations with plants in operation which have been conducted by eminent authorities for a number of years have practically eliminated the old dispute, as they have shown that under ordinary conditions the forenamed refrigerating agents are in practice quite equal in their efficiency, so that a preference for one system over the other on that account is not justified.

There are, however, features of peculiarity of each system which may be called advantages or disadvantages. For instance, the latent heat of vaporization of ammonia per pound is greater than that of any of the other agents; this is an advantage, inasmuch as it reduces the losses that occur in cooling the liquid ammonia to the temperature of the evaporating gas; the liquid ammonia, being at or near the temperature of the water used on the condenser, carries this heat with it into the evaporator, where it is absorbed by the evaporating gas, constituting a loss which is equal to the specific heat of the liquid refrigerant multiplied by the fall of temperature between that of the condenser and the evaporator. These losses are shown in Table II, and it will be seen that from this point of view carbonic acid is at a disadvantage.

The same table shows that there are 400 units of heat available per cubic foot of gas in carbonic acid, as against 28 in sulphur dioxide and 80 in ammonia, and as compressors are built to handle volumes and not weights, it follows that the advantage is largely in favor of carbonic acid, as it requires a cylinder volume which is only one-fifth of the volume necessary for the ammonia system, while the volume required for the sulphur dioxide machine at even capacities is 13.5 times as large.

The fact that for a given capacity the carbonic acid compressor is the smaller, gives the advantage of a small cylinder bore, small piston and valves, reduction of frictional losses and less liability of mishap. It will thus be seen that the ammonia system is regarded as the most advantageous with regard to the heat of evaporation per pound, while the carbonic acid system has the advantage with relation to the heat of vaporization per cubic foot.

Sulphur dioxide machines requiring large volumes operate with the least pressure, which is claimed to be an advantage from the standpoint of the manufacturer of that system, while the much higher pressure—900 to 950 pounds—necessary in the liquefaction of carbonic acid has often been alluded to as a disadvantage.

As a matter of fact pressures are nowadays of very little importance; all engineers agree that with the present excellence of

material and tools all pressures may be readily overcome with a good margin of safety. Besides, it must be remembered that a small cylinder with high internal pressure can be made just as safe as a large cylinder with low internal pressure.

All carbonic acid machines are provided with safety valves, which remove the danger of bursting, and even of accidents caused through carelessness on the part of the operator, and it is a fact that with thousands of these machines in operation no explosion or bursting—outside of the breaking of safety plates—has ever occurred.

In view of these facts, the carbonic acid machine is to-day considered the safest machine under all conditions, and the feature of high pressure is of no importance to the user, as he is not affected by it.

Theoretically, the efficiency of the carbonic acid system is about 12 per cent. less than that of the ammonia and sulphur dioxide machines. There are, however, many practical compensating features connected with this system which enable it to more than make up that loss. Stetefeld has found by tests and corresponding calculations of the indicator diagram that the losses, consisting of radiation in the refrigerator, clearance, the resistance of the gases on their way from the refrigerator to the compressor and when passing the suction valves, and lastly, piston and valve leakage, average 48 and 49 per cent. in the ammonia and sulphur dioxide systems and not more than 25 per cent. when carbonic acid is used as the refrigerating agent.

The piston leakage alone averages about 25 per cent. in ammonia and sulphur dioxide machines and only 9 per cent. in carbonic acid machines. This leakage is so small in the carbonic acid machine because the piston and rod packing consists, with normal cooling water, of leather cups, and these cups fit so tightly to the cylinder and the piston rod that very little carbonic acid leaks by the piston and out through the outer end of the stuffing box. The frictional losses in the suction line are small in this system, because the velocity of the gas is smaller than in the others on account of the ample dimensions of pipes and valves—although these dimensions do not nearly reach those required in either of the other two systems on account of the great density of the carbonic acid gas.

It will therefore be seen that the practical over the theoretical volume must be enlarged 48 and 49 per cent. in ammonia and sulphur dioxide machines and only 25 per cent. in carbonic acid machines, basing the calculations on water of below 65 degrees F.

Table III explains the comparative value of the three refrigerants in practical operation. In computing this table, Mollier's data regarding the properties of carbonic acid, and the Lorenz and Stetefeld data of the useful heat of vaporization, as per Table II, have been adopted.

TABLE III.

COMPARATIVE VALUE OF CARBONIC ACID, SULPHUR DIOXIDE AND AMMONIA IN PRACTICAL OPERATION.

SUBSTANCE.	Theoretical Compr. Volume per ton of Refr. Cap. per min. in cu. ft.	Losses due to Radiation in the Refrigerator in per cent.—Brine System.	Loss Due to Clearance in per cent.	Loss Due to Friction in the Suction Line and Valves in per cent.	Loss Due to Leakage of Piston and Discharge Valves in per cent.	Actual Required Compr. Volume per ton of Refr. Cap. per min. in cu. ft.	Volume in cu. ft. per ton per min. Allowed in Practice.	Theoretical Efficiency per Indicated H. P. in B. T. U.	Practical Efficiency per Indicated H. P. in B. T. U.
Carbonic acid	0.49	6	5	4	9	0.60	0.61	14855	13370
Sulphur dioxide	7.04	6	6	14	23	10.556	10.6	16673	13300
Ammonia	2.4	6	6	11	25	3 56	4.00	16673	13300

The feature of cooling water, temperature as well as quantity, is of importance to each of the three systems, especially in the case of the carbonic acid machine, owing to the fact that its critical temperature is not a great deal higher than the summer temperature of ordinary river water. When the initial temperature of the condenser water rises above 70 degrees F., it is advisable to use a greater quantity of cooling water, in order to maintain an average condenser temperature of around 75 degrees; if this rule is carried out, the maximum efficiency of the machine will be maintained.

With temperatures above 75 degrees the efficiency of the carbonic acid machine diminishes more rapidly than with the other two systems. The decrease in the efficiency, however, has generally been overestimated, as it is a fact that machines using condenser water of 88 and 90 degrees F. still perform refrigerating work averaging 70 per cent. of the work which it is possible to accomplish with condenser water of normal temperature.

A number of these machines installed on board ships running from cold water into the Gulf Stream have come under the writer's close observation, and the falling off in the efficiency when leaving water of 72 degrees F. at Cape Hatteras and entering the Gulf

Stream with temperatures of between 86 and 89 degrees F. did not exceed 25 to 30 per cent.

Notwithstanding the fact that the efficiency of the carbonic acid machines diminishes with sea water of high temperature for condensation, it is estimated that 90 per cent. of the refrigerating machines installed on board ships use carbonic acid as the refrigerating agent, which indicates that the considerations of safety are of much greater importance than the question of maximum efficiency. This is also borne out by the fact that the only hold which the cold air machine ever had on the refrigerating industry was its use on board ships, simply on account of the harmlessness of its process and in spite of the fact that its refrigerating duty per horse power is only one-sixth of the refrigerating work per horse-power of any of the three vapor-compression machines.

Comparative Characteristics of Ammonia and Carbonic Acid.—In comparing the characteristics of the three gases it will be found that while ammonia and sulphur dioxide have a sharp, penetrating odor, carbonic acid is odorless. The two former are decidedly corrosive in their action upon metals, while the latter's action, on the other hand, is entirely neutral. Ammonia dissociates into its constituent parts at higher temperatures; carbonic acid does not decompose under any condition. Accidents through lack of condenser water, carelessness on the part of the operator, causing burstings and explosions, do occur with ammonia machines. In the case of carbonic acid such liabilities to mishap are practically eliminated. Ammonia as it exists in the refrigerating system, i. e., mixed with lubricating material and other impurities, is combustible, while carbonic acid is a positive fire extinguisher. In the construction of ammonia and sulphur dioxide machines only iron and steel can be used, while any suitable metal can be employed in the construction of the carbonic acid system. A fraction of 1 per cent. of ammonia in the atmosphere cannot be endured for any length of time, while 8 per cent. of carbonic acid in the air can be inhaled without danger. Carbonic acid does not act upon the blood; it only deprives the respiratory organs of the necessary oxygen, and this constitutes the only danger in inhaling large volumes of carbonic acid. In the case of a leak it does not endanger the life of the attendant, nor does it spoil the food products with which it may come in contact; on the other hand, a leak may be detected by its odor when the charge has been made odoriferous by alcohol impregnated with camphor. In the case of a leak it is most always possible to stop it without interrupting the operation of the machinery. Impurities, such as air or water

in the system, do not influence it to any extent. Lubricating material and water absorb very little carbonic acid; the system remains clean and maintains its full radiating efficiency. Large intercepters and rectifying apparatus are not required, which adds to its simplicity.

The cheapness of liquid carbonic acid has greatly stimulated the use of carbonic acid refrigerating machines. This gas is required in a number of extensive industries, and can be bought anywhere at the low price of a few cents per pound.

In the brewing industry the carbonic acid required in the refrigerating apparatus may be obtained from the fermenters; in that case it costs practically nothing to replenish the charge from time to time, especially in an establishment that is equipped with a gas collecting and carbonating outfit.

Properties of Carbonic Acid.—Carbonic acid gas is much heavier than air; its specific gravity at atmospheric pressure is 1.529 (air = 1). According to Regnault, Schroeter, Mollier and Luhmann, its boiling point at atmospheric pressure lies at 78.2 degrees C., or 109 degrees below zero F. Mitchell differs with 124 degrees below zero F.; 109 degrees below is considered correct. It solidifies at the same temperature, i. e., 110 degrees below zero. The specific heat of carbonic acid gas at constant pressure is 0.2167 (air = 0.2375); at constant volume it is 0.1714; of the liquid it is 0.79 and not 1 as is variously stated. Mitchell found the specific gravity of the liquid at 32 degrees F. = 0.93, at 42 degrees F. = 0.8825, at 47.3 degrees F. = 0.853, at 65.3 degrees F. = 0.7385, and at 86 degrees F. = 0.6. This is considered too low. According to Luhmann, the specific gravity at 14 degrees F. = 0.9951, at 32 degrees F. = 0.947, and at 68 degrees F. = 0.8266. The latent heat of vaporization per pound at 32 degrees is also variously given as 108, 100, 98 and 92 B. T. U. Mollier's figure of 100 B. T. U. per pound at 32 degrees F. has generally been accepted. Andrews established the critical temperature, above which no liquefaction occurred under any pressure, to be + 30.92 C. or 88 degrees F. Thilorier and Natterer produced quantities of crystallized carbonic acid through rapid evaporation. If these crystals are compressed they have the appearance of chalk, evaporate slowly and have a specific weight of 1.2 (water = 1).

Schroeter and Mollier, as a result of experiments, have recently published a table giving the exact properties of carbonic acid. Mollier's values differ slightly from those given by Schroeter; they are believed to be more correct, however, and have been generally accepted. Mollier's figures are given in Table IV, the values having

been directly altered into British Thermal Units, without changing them by interpolation, for the purpose of giving values for even increments of 50 pounds per square inch.

TABLE IV.

PROPERTIES OF SATURATED CARBONIC ACID GAS. (TRANSFORMED FROM MOLLIER'S TABLE INTO ENGLISH UNITS.)

Pressure Above Atm. in lbs. per Sq. Inch.	Temp. in Deg. Fahr.	Spec. Volume of Liquid in Cubic Feet per lb.	Specific Volume of Saturated Vapor in Cubic Feet per lb.	Latent Heat in B. T. U. per lb.	Heat Equiv. of External Work in B. T. U. per lb.	Internal Latent Heat in B. T. U. per lb.
284	—5.0	.0161	.3182	119.86	15.98	103.88
355	+9.0	.0165	.2497	113.26	15.41	97.85
427	+20.7	.0170	.2028	106.94	14.76	92.18
498	+31.2	.0176	.1698	100.44	14.06	86.38
569	+40.5	.0181	.1435	93.76	13.26	80.50
640	+49.0	.0188	.1232	86.90	12.42	74.48
711	+56.7	.0194	.1059	79.65	11.45	68.20
782	+63.8	.0204	.0919	71.73	10.39	61.34
853	+70.3	.0213	.0795	63.22	9.22	54.00
924	+76.7	.0226	.0676	52.87	7.74	45.13
995	+82.6	.0249	.0563	39.29	5.79	33.50
1066	+88.2	.0307	.0385	10.51	1.56	8.95

Theory of the Carbonic Acid Machine.—During the various phases of the cycle the carbonic acid gas enters the compressor in a saturated condition. When compressed it is partially saturated and partially superheated, or entirely superheated. The latter case takes place when the gases enter the compressor in a dry condition. The cooling, which takes place in the condenser, lies partly within the saturated and partly within the superheated zone, provided the condenser temperature permits pressures below the critical, viz., 75 atms.; when higher pressures are required the cooling takes place entirely within the superheated zone. In the latter case the condenser work consists in the removal of the heat from the superheated gas and the cooling of the carbonic acid to nearly the initial temperature of the condenser water. When pressures below 75 atms. are permissible the condenser work consists of the removal of the sensible heat from the gas, together with the latent heat of liquefaction, and the cooling of the liquid to nearly the initial condenser water temperature.

The sum total of the heat abstracted is therefore the heat contained in the gas when it enters the condenser, minus the heat still remaining in the liquid after it leaves the condenser. The heat so abstracted is partially made useful in the refrigerator during the

evaporation of the liquid, and the sum total of the latent plus the sensible heat is the same on both sides of the expansion valve, within the small frictional loss occasioned through passing the latter. The difference of the heat abstracted in the condenser and the heat liberated in the evaporator is the equivalent of compressor work.

On comparing the theoretical efficiencies of the carbonic acid machine, when working with wet or dry gas, it will be found that machines working with dry gas are capable of performing a refrigerating duty which exceeds that of the wet system by about 10 per cent. When manufacturers, nevertheless, adhere to the wet system it is simply the logical outcome of practical considerations. The packing of the piston consists of leather cups. This material does not withstand temperatures above 200 degrees F., and in order to keep them pliable it is necessary to remove the heat of compression by means of wet gases from the evaporator. Metallic packing, with its consequent greater piston leakage, and dry gas compression offer no gain in comparison with the wet system; any theoretical gain on the one hand being offset by the advantage of using a tight piston packed with cupped leathers on the other.

The fact that during compression the gas is in the superheated state, and that there are considerable changes in its entropy with temperatures and pressures above the critical, explains why the refrigerating work of this system does not cease with high condenser temperatures. It also appears that under these conditions partial liquefaction does occur at the expansion valve. The investigations on this point, however, have not yet been completed.

Constructional Details.—Owing to the practical inability of English and American manufacturers to secure castings that will withstand the high internal pressures without a large percentage of such having to be discarded as defective or porous after they are half finished, they have adopted soft forged steel as the material for the cylinders. This material requires considerable lathe and drill work for the bore, ports and other openings. When finished, however, it is hardly necessary to subject them to tests. In Germany the cylinders consist of high-grade, close-grain castings, and complaints regarding inferior, porous, or castings that are too hard are rarely met with. The bore of the carbonic acid machine should be about one-fourth of its stroke; for instance, a machine of 20 tons capacity having a bore of 4 inches should have a stroke not shorter than 16 inches. It will also be found that a machine of 5-inch bore by 20-inch stroke will conform very well to all other corresponding details of construction. This latter machine will easily have a

capacity of 40 tons, which shows the influence of a slight increase in the bore and stroke upon the capacity.

A long piston is of great advantage in reducing the wear and tear of the piston rod. The relation of diameter and length of piston is about 1 : 2.5. The suction port should be so placed as to allow the gas to cool the whole cylinder effectively before reaching the suction valves. These valves are usually placed in a horizontal position, but as they are comparatively small and of light weight, it does not require a very heavy spring to close them. A long stem guide keeps them in a central position, so that there is an even wear. The discharge valves are of the usual poppet design; they are placed vertically, and are therefore always in a central position. The area of the discharge valve is one-seventh that of the piston, and of the suction valve one-half that of the piston. There is no difficulty in allowing this area for the suction valve located in the cylinder head, but on the piston rod end two valves are frequently used, as there is hardly sufficient room for one valve having the required area. The width of the seat should not exceed 0.1 to 0.12 of the valve disc diameter, and an angle of 70 to 90 degrees for the discharge valve seat and one of 60 to 75 degrees for the suction valve are considered good practice. A valve lift of 0.33 of the diameter for the suction valve and 0.28 of the diameter for the discharge valve are figures which will prove satisfactory. Strict attention should be paid to the valve spring, which is often too stiff. A spring tension of 8 to 9 pounds for the suction valve and 10 to 11 pounds for the discharge valve will be found ample.

A well-proportioned valve, properly adjusted, is of much more importance than is usually accorded it. Such a valve will hardly be heard in the carbonic acid machine, owing to the great mass of metal in the cylinder, which muffles the sound, and also to its own lightness. The piston rod is of the same diameter as is customary in ammonia machines.

The most essential point is the stuffing box. Owing to the high internal pressure, as well as to the comparatively large piston rod, it is necessary to divide the stuffing box into several chambers, consisting of removable lanterns, which are so arranged that the pressure is reduced by steps. The chamber next to the cylinder bore takes care of the gas which leaks from the cylinder; a controlling device is usually connected to this chamber by means of which the gas is returned to the suction side at a pressure higher than that of the evaporation and lower than that of the condenser. The next chamber is kept under oil by a force pump, which

forces the oil into it at a pressure slightly above that of the suction. An oil outlet, controlled by a ball valve, leads from this chamber to the suction port of the compressor, so that a small amount of oil, together with an occasional bubble of gas, enters the compressor at this point. "Garlock" or any other soft packing is used at the outer end of the stuffing box merely as a wiper of the lubricating material, so as to prevent oil leakage.

Leather cups are used almost exclusively as the packing material, they having given much better satisfaction than any other known method of packing. In packing the stuffing box with this material the glands must be drawn up tight, as no provision for expansion of the material need be made in this case; only the outer nut, which holds the "Garlock" packing in place, is left comparatively loose. The lifetime of this packing is a season or more with ordinary care.

A simple trap is used to separate the oil from the gas; it is usually connected in the direct line of the discharge pipe between compressor and condenser, as it is of small dimensions and can easily be supported.

Safety valves are always used. The location of these valves on the compressor is on the discharge port, between the discharge valves and the delivery stop valve, so that they also serve the purpose of protecting the compressor in the case of careless starting, without opening the delivery stop valve. These valves are usually provided with a cast-iron diaphragm, proportioned to break at a pressure of about 150 atmospheres.

When condensing water of temperatures above 75 degrees F. is used, it is advisable to provide a special liquid cooler, for the purpose of reducing the temperature of the liquid before it passes the expansion valve. Submerged, atmospheric and double pipe condensers of the same surface as is customary with ammonia machines are used; and the same rules prevail regarding the surface of the evaporator pipe, with this difference, that the evaporating temperature may readily be dropped much below zero F. without causing a great difference in the pressures of the evaporator and the condenser, or, in other words, without changing materially the ratio of compression, which ordinarily is 1 : 3.

While it is correct that the theoretical efficiency of the carbonic acid system does not reach that of the ammonia machine, owing to the greater percentage which the specific heat of the liquid carbonic acid bears to the latent heat of evaporation, yet the practical efficiency of the machine does not bear out this theoretical deduction,

and it was found that the compensating features which make up for the above loss consist in less piston leakage, a smaller depression of the suction line, and slightly smaller losses through clearance. A comparison of the theoretical diagram with that obtained by the indicator will be of considerable assistance in explaining this point, and it will then be seen that in practice the three most prominent refrigerating agents, ammonia, sulphur dioxide and carbonic acid, are quite equal in efficiency and economy of operation.

(*In the absence of Mr. Goosmann his paper was read by Oswald Gueth. It was not discussed.*)

No. 9.

Discussion of the Topic—DOES A 100-TON AMMONIA COMPRESSION PLATE ICE-MAKING PLANT OR A 100-TON ABSORPTION PLATE ICE-MAKING PLANT EQUAL IN ECONOMY A 50-TON COMPRESSION MACHINE IN COMBINATION WITH A 50-TON ABSORPTION MACHINE, USING THE EXHAUST OF THE COMPRESSION MACHINE FOR OPERATING THE ABSORPTION MACHINE?

By Henry Torrance, Jr., New York, N. Y.

(Member of the Society.)

In order to discuss economies of ice machines it is necessary to assume a certain set of conditions, for the same machine must work the same under a given set of conditions.

An engineer has two machines, and one will work a little better than the other. He gets superstitious and thinks that no two machines work alike.

There is generally a great deal of superstition among operating engineers, and in fact among many people who run machines. They become so used to watching for results and see so many queer things that they lose sight of the theory on which the results must be based.

Let us assume an average set of conditions.

Boilers.—Ice plants are generally put up as independent units, built complete in themselves, and hence we can assume any type of boiler or steam pressure desired. We will assume 100 pounds pressure for simple engines and 140 pounds for compound engines, and 8.5 pounds of steam per pound of coal evaporated from feed water at 130 degrees under a steam pressure of 140 pounds.

Water Supply.—Most ice factories obtain their water supply from wells; in fact, factories should be located, if possible, where a good water supply is available free of cost. Let us assume that the water is 60 degrees and can be pumped from a well. Quantity, 400 gallons per minute for all purposes; total discharge pressure 20 pounds and suction lift 30 pounds = 11.6 net horse power; assuming a triplex pump of 75 per cent. efficiency, then the brake horse power to run the pump would be 14.5.

Temperature of Freezing.—With large plate surfaces, a high

suction pressure can be used. Some go to the other extreme and use very small surfaces with suction pressures of zero, or even a slight vacuum. Probably 10 pounds suction pressure is a fair average condition.

Thawing System.—Assume a small brine pump is used for thawing edges of cakes. This would take about 1 horse power while it runs, and an average might be assumed of .4 horse power per hour at pulley of a triplex pump driven by belt.

Crane.—Assume that a power crane is to be operated for lifting ice, which would take about 4 horse power. There would also be the traveling of the crane, moving of tipping table and a small ice lift, making an average load of, say, 3 horse power throughout the day. If this is electric, with losses of 25 per cent., then we would require 4 electric horse power per hour at switchboard for twenty-four hours.

Cutting Ice.—Assume an electric saw is used, requiring an average of 3 electric horse power per hour at switchboard for twenty-four hours.

Agitation.—Assume an air agitator requiring 5 horse power to operate it, delivered to the flywheel by belt.

Boiler Feed.—Assume 12 gallons per minute pumped from 0 pounds to 140 pounds, which would require .98 net horse power, and assuming a triplex belt pump, this would be 1.3 horse power delivered to pulley by belt.

Air Pump for Compression System.—Assume 3 horse power is required to run vacuum pump of condensing engine.

Ammonia Pump of Absorption System.—Assume this is 6 net horse power, which would be 8 horse power delivered to the pulley by belt.

Steam Required by Absorption System.—Assume the ice machine generator requires 50 pounds of steam per hour at 1 pound pressure for each ton of ice made per day of twenty-four hours, under conditions of freezing mentioned above.

Power to Drive Compressor.—Assume a compressor requires 3 indicated horse power in the steam cylinder to make 1 ton of ice per day, under the freezing conditions mentioned above.

Economy of Engines.—Assume a "Corliss" engine with 100 pounds steam pressure and 1 pound exhaust pressure and 100 revolutions per minute requires 27 pounds of steam per indicated horse power per hour.

Assume a compound condensing "Corliss" engine with 140 pounds steam pressure, 27-inch vacuum, 50 revolutions per minute,

requires 18 pounds of steam per indicated horse power in steam cylinders.

Economy of Compression Plate Ice Plant.—Assume a 100-ton compression plate ice system in which the compressor is driven by a compound condensing engine, with pumps driven by belt from line shaft, and crane, etc., driven by dynamo belted from line shaft. We must add 20 per cent. to belt horse power of pumps and motors to cover the friction and electric losses.

Then the horse power required would be as given in Table I.

TABLE I.

HORSE POWER REQUIRED BY AUXILIARIES OF COMPRESSION PLATE ICE PLANT.

AUXILIARIES.	Net Pumping H. P.	H. P. at Belt.	Shaft Friction 20 Per Cent.	Brake H. P. at Engine.	Friction of Main Engine. 10 Per Cent.	Indicated H. P. of Main Engine 10 Per Cent.
Water pump	11.6	15.5	3.10	18.6	1.86	20.46
Thaw pump	.3	.4	.08	.48	.05	.53
Agitator	4.3	5.	1.	6.	.6	6.6
Boiler feed pump	.98	1.3	.26	1.56	.15	1.71
Air vacuum pump	....	....	....	3.	.3	3.3
Electric light and conveyors	....	....	....	....	....	10.
Electric crane	....	4.	....	4.4	.44	4.84
Electric motor for cutting ice	....	3.	....	3.3	.33	3.63
						51.07

Total indicated horse power of engine to run auxiliaries.	51.07
Indicated horse power of compressor engine, 100x3.....	300.
Total power required.....horse power,	351.07
Steam required per hour at 140 pounds pressure in a compound condensing engine using 18 pounds per indicated horse power per hour.....pounds,	6,318
Total steam required per twenty-four hours.....pounds,	151,632
Pounds of coal, assuming feed water 130 degrees, steam pressure 140 pounds, and evaporation 1 : 8.5.pounds,	17,839
Equivalent in tons of coal per 100 tons of ice.....tons,	8.92
Tons of ice per ton of coal.....tons,	11.2

Economy of Absorption Plate Ice Plant.—Assume a 100-ton plate ice plant in which the auxiliary machinery is run from a line shaft driven by a "Corliss" engine operating with 100 pounds steam pressure, 1 pound back pressure, 100 revolutions per minute and using 27 pounds of steam per hour per indicated horse power. The

exhaust from the engine is used in the generator of the absorption machine.

The horse power required would be as given in Table II.

TABLE II.

HORSE POWER REQUIRED BY AUXILIARIES OF ABSORPTION PLATE ICE PLANT.

AUXILIARIES.	Net Pumping H. P.	H. P. at Belt.	Shaft Friction 20 Per Cent.	Brake H. P. at Engine.	Friction of Main Engine.	Indicated H. P. of Main Engine.
Water pump	11.6	15.5	3.1	18.6	1.86	20.46
Thaw pump	.3	.4	.08	.48	.05	.53
Agitator	4.3	5.	1.	6.	.6	6.6
Boiler feed pump	.98	.91	.26	1.56	.15	1.71
Ammonia pump	6.	8.	1.6	9.6	.96	10.56
Electric crane	....	4.	....	4.4	.44	4.84
Electric light and conveyors	....	....	....	....	....	10.
Electric motor for cutting ice	....	3.	....	3.3	.33	3.63
						58.33

Steam required by "Corliss" engine (with 100 pounds steam pressure, 1 pound back pressure), 100 revolutions per minute at 27 pounds per hour per indicated horse power.....pounds, 1,574.9

Cylinder condensation at 20 per cent.....pounds, 314.9

Steam required by absorption machine for 100 tons of ice at 50 pounds per hour per ton.....pounds, 5,000

Total steam required, assuming exhaust from "Corliss" engine is used in generator.....pounds, 5,314.9

Total steam required per twenty-four hours.....pounds, 122,560

Assuming that with 130 degrees feed water and 140 pounds pressure, evaporation is 8.5:1, then with feed water at 210 degrees and steam pressure of 100 pounds, corresponding to evaporation of 9.2:1, this would equal in coal.....pounds, 13,860

Tons of coal required to make 100 tons of ice.....tons, 6.93

Tons of ice per ton of coal.....tons, 14.4

Economy of Combination Compression and Absorption Plate Ice Plant.—Assume a 68-ton absorption plate ice plant, a 32-ton compression plate ice plant driven by a plain "Corliss" engine at 100 pounds steam pressure, 1 pound back pressure and 50 revolutions per minute, using 29 pounds of steam per hour per horse power, and a pumping plant requiring 55.7 indicated horse power of a plain "Corliss" engine at 100 pounds steam pressure, 1 pound back pres-

sure and 100 revolutions per minute, using 27 pounds of steam per hour per horse power, in which the exhaust of each engine is used in the generator.

Steam required per hour by 68-ton absorption plant at 50 pounds per hour per horse power	pounds,	3,400
Steam required per hour for driving pumps of 55.7 indicated horse power at 27 pounds per hour per horse power	pounds,	1,504
Steam required per hour for driving a 32-ton compressor = 96 indicated horse power at 29 pounds per hour per horse power	pounds,	2,784
Total steam used by plant	pounds,	4,288
Total steam per day	pounds,	102,912
Coal per day at 1 : 9.2	pounds,	11,186
Tons of coal to make 100 tons of ice	tons,	5.59
Tons of ice per ton of coal	tons,	17.8

DISCUSSION.

A. P. Criswell.—I would like to ask Mr. Torrance what proportion of steam he guesses or assumes would be used in a low-pressure absorption machine as compared with the high-pressure steam used in an ordinary absorption plant. How much more is required than at the pressure ordinarily used? I have made some experiments with absorption machines and found it necessary to use about 1 ton of low-pressure steam to get 1 ton of refrigeration, although I must admit they were very poor absorption machines.

Henry Torrance, Jr.—If you use exhaust steam at low pressure, there is less total heat per pound than at high pressure, but practically the amount of steam used at low pressure is about the same as at high pressure.

A. P. Criswell.—I do not exactly remember the steam table. We know that at 1 pound back pressure the temperature of the steam would be only a little over 212 degrees F., and at the pressure ordinarily used it is much higher. Of course, the total heat allowance would depend almost entirely upon the pressure of the steam, and, if Mr. Torrance figures it, he will find it requires just about twice as much steam at a low pressure as it would at a high pressure.

R. L. Shipman.—The amount of heat available in the steam for evaporating is really greater at the low pressure than at the high pressure. I notice that he assumed 20 per cent. loss of the water from the engine from cylinder condensation. This is usually taken as about the amount of loss of heat from the steam, but we get that

back in the steam during re-evaporation, so that we would not have 80 per cent., as he assumed, but would come nearer having 90 per cent., and that would give us only 10 per cent., and 10 per cent. is a sufficient allowance.

I notice that the back pressure of the ammonia is taken at 10 pounds. I do not remember ever having seen an ice machine working at 10 pounds back pressure in the manufacture of ice.

Henry Torrance, Jr.—Plate ice?

R. L. Shipman.—Even for plate ice I take exception. In making ice 25 per cent. of the heat to be removed is consumed in cooling the water from 80 to 32 degrees. This heat can be removed at a much higher back pressure, making the average back pressure not less than 15 pounds. In the case of a four-cylinder set, one cylinder might be used to work on this high back pressure by providing it with a separate suction line. But, of course, it would be better to work this high back pressure by a separate compressor so as to have it under better control. A loss of 25 per cent. is assumed in increasing the head pressure on the machine to 50 pounds. It will not require the 50 pounds; even 50 pounds will not figure 25 per cent. in horse power, or loss in efficient capacity. I have learned from the tests that I have made that 10 per cent. will cover all that. Increasing the head pressure from 200 pounds to 250 pounds will increase the mean effective pressure and thus the horse power very little, certainly not more than 10 per cent.

Gardner T. Voorhees.—I would like to make two assumptions, and I would like to tackle that proposition from a different point from which it has been tackled, and the assumptions I want to make are these: I had occasion to conduct a series of tests on absorption machines. I took the temperature and the quality of anhydrous and aqua ammonia at every part of the machine. I found that the ammonia tables only went to 28 per cent. aqua, and I was obliged to make tests and deduce tables for higher percentages of ammonia. I assume my tables to be somewhere near correct; and I also assume that my tests show that the limits of working an absorption machine are fixed by the properties of the aqua ammonia, which are as well known as the properties of steam, if we have a correct table. From my study of the matter I believe there would be such a small difference in the percentage of the strength of the strong liquor and the weak liquor, if operated at 1 pound back pressure, that the work of the still would be very excessive, and that the machine, although it might do refrigeration, would not be a practical operating machine. In other words, unless there is something

new in the absorption machine that is not generally known, with condensing water at 70 degrees F., or even at 60 degrees, an economical result could not be obtained by using 1 pound back pressure to operate the generator.

Henry Torrance, Jr.—I would like to say that it is possible to run a 1 pound back pressure machine and run it well; at least that is my opinion, and it has been borne out by the facts as near as I can tell.

The President.—I think there is no possible question of that; in fact, such machines are operated on from 1 to 2 or 3 pounds—I won't say exactly at 1 pound—if the machine is designed for it, and I think a study of the tables showing the relation between the pressure, the temperature and the strength of aqua ammonia will establish a perfect theory for the operation of such a machine. I do not carry the figures in my head very well, but my recollection is that such a machine would operate with 60 degree water on a range from about 36 per cent. strength of strong aqua to about 26 or 27 per cent., and that, with an exchanger of reasonable size, it would render the operation of the distillation and the condensation of the ammonia with water of that temperature perfectly feasible, theoretically, and as a matter of fact it is done.

The question as to the amount of steam used is a very simple one. The amount of heat which is necessary to drive out a pound of ammonia from its solution in water must be the latent heat due to the pressure and temperature and a certain amount of superheat, and a certain amount of heat which we call the heat of disassociation, which is the heat necessary to break the somewhat mysterious bond between the water and the ammonia.

The only amount that increases would be the superheat and the heat of disassociation; therefore, as a matter of practice, it has been found that, whether the steam pressure be high or low, granting a reasonable sized exchange, the amount of steam per ton of refrigeration, or per pound of ammonia boiled out of the solution, is practically constant. The heat of the steam utilized is, of course, the latent heat of the steam, and it is greater in amount as the steam is lower in temperature, and this compensates for some other items on the other side. So, as a matter of practice, with a reasonably well designed machine and with a reasonably good exchanger, I think I can testify to one of Mr. Torrance's assumptions, and that is, the amount used will be practically 30 pounds of steam per hour per ton of refrigeration, which would make his assumption of 50 pounds per ton of ice produced a reasonable one.

Edgar Penney.—I understand that this is a highly specialized apparatus, and that he has arranged his absorption machine to show that.

D. S. Jacobus.—It is very hard to criticise a paper like this, and to say anything about the accuracy of the figures. On the whole, however, the conclusion arrived at seems a probable one, viz., that a combined compression and absorption plant may be more economical for some classes of work than either plant would be when operated by itself. In many cases it seems to me that it would have been better for the author to have said in presenting his paper that certain figures were those obtained in practice and not an assumption on his part. For example, take the steam consumption given for the two types of engines which he considers. If I may be allowed to do so, I will take pleasure in going over the figures later on with a view of presenting the results to the society.

Henry Torrance, Jr.—I would like to have Professor Jacobus do that very much, and it would help us all.

The President.—I am very sure we should all be glad to have the professor do that.

Gardner T. Voorhees.—I would like to know whether there is an absorption plant operating in New York City with condensing water at 60 degrees on 1 pound back pressure. If there is I would like to go and see it. I know of lots of plants that are running with less than 60 degree water that are throwing away plenty of exhaust steam at more than 1 pound pressure. I would like to see a plant that is running at 1 pound back pressure, see the gauge tested, and see that it was doing the business.

Henry Torrance, Jr.—I can show Mr. Voorhees a plant like that, and more than one. There seems to be a great deal of skepticism about this. You tell a man that, and he does not believe it. Then another man says, if he finds it so, it is not any good anyway; you use twice as much steam.

A. P. Criswell.—I would like to put myself on record as not being one of the skeptical ones. I want to get at the actual facts. Of course, Mr. Torrance has stated that he has guessed at one or two things and assumed the rest. I believe in his system, only I think I would turn the figures around and put in a 68-ton compression machine to run the 32-ton absorption machine, but I know that you can run an absorption machine at 1 pound back pressure. I have seen it done, but it required about a ton of steam to get a ton of refrigeration. Mr. Torrance has enough of these machines run-

ning, and he may be able to tell us how many pounds of steam they use to get a ton of refrigeration.

Henry Torrance, Jr.—If you allow the steam to blow through the generator coil, there is no limit to the amount of steam that you may use.

Gardner T. Voorhees.—I want to put myself on record that I did not intend to say that such a machine would not work, but that I did not think it would work practically and economically.

J. Shipman Louis.—I have just come in contact with one of these skeptics, who was out West. He had not decided whether he would put in an absorption or a compression plant, but it was stated that absorption plants of a certain kind were operating with 1 pound pressure. He took occasion to investigate, and he said he was unable to find any plant in New York City that was operating with 1 pound pressure; that while he went into some of the plants stated to have been operated at that pressure, on investigation he found them working at 15 pounds pressure. Now, I am anxious to see one of these plants that operate with 1 pound pressure.

Thomas Shipley.—I was one of those skeptics, and spent some of our company's money to find one of those one pounders. I sent an expert around this man's town, and they always made some excuse; they could do it all right, but they were not doing it that day. It always appeared for some reason they were not doing it.

Henry Torrance, Jr.—When you get down to working with 1 pound you have to run the machine carefully, and if there is air in the system it won't work. The way a machine is ordinarily run it may be 2, 3 or 4 pounds, or, in fact, it may be anything, but a machine can be run with 1 pound.

Edgar Penney.—This reminds me a little bit of a Mississippi skipper who stated that his boat could run on dew.

Henry Torrance, Jr.—I would like to add one word: In the assumption for the high temperature of water, 82 degrees, I said it would be necessary to have 10 pounds pressure for the absorption machine. Suppose we increase that 5 pounds, it won't alter its economy at all; if you increase it 10 pounds it won't make any difference.

R. L. Shipman.—A proposition of this kind is misleading, unless it is the entire commercial problem. There are certain elements left out, and one of these is the amount of condensing water. I believe that it is well established that with the absorption machine this amounts to considerably more than with the compression machine.

Henry Torrance, Jr.—I assumed 400 gallons per minute for 100 tons of ice.

The President.—Would it not be true in cases of this kind, where you are taking the absorption plant alone, that it would not make much difference in your first results about the back pressure on the auxiliaries, whether it was 5 or 10 or 15 pounds?

Henry Torrance, Jr.—It would not make any appreciable difference what the pressure was.

The President.—The idea, as I understand it, is that the back pressure on these auxiliaries would make no difference. So long as they use less than 50 pounds or thereabouts per ton of ice made it would make no difference what the back pressure was; supposing, of course, that increased back pressure would result in economy.

Henry Torrance, Jr.—Yes, it makes no difference how much back pressure you put on so long as the exhaust does not affect the steam which the compressor uses.

Gardner T. Voorhees.—I am pretty well convinced that you can get gold out of sea water, but I do not think it pays to try it; but I would like to see that 1-pound plant. Put it on record, where we can all go and see it. Let it be a matter of record.

Henry Torrance, Jr.—As I said before, when you get down to 1 pound they are not always run under that pressure. The plant at the Stock Exchange down town has never had, so far as I know, more than 4 pounds pressure on it, and that has had condensing water as high as 78 degrees. The brine temperature runs from 25 to 30 degrees.

Gardner T. Voorhees.—What is the pressure in the absorber?

Henry Torrance, Jr.—From 20 pounds up. I am assuming that pressure, but the pressure might be 10 pounds with 60 degrees water. In practical running you won't get a plant to run with 1 pound steam pressure in the generator unless you have some system to keep it down. It generally runs up to 2 or 3. You can do it if you have the proper organization.

S. J. Rowe.—I had occasion to observe the plant at the Hotel Astor, and that plant ran on 2 pounds pressure at that time.

R. L. Shipman.—The amount of pressure necessary in that case depends upon the amount of heat you want to transfer per unit of cooling surface, and to keep that pressure down you must increase the coil surface. The amount of heat transferred depends upon the mean temperature between the two sides of the cooling surfaces. So when we come down to low mean temperatures between the two sides we find that the work done by the cooling surface runs

down very rapidly, and that is the reason that these plants designed for low pressures run higher. They are designed for perfect conditions which are never obtained.

The President.—That is a thing that goes without saying, that your low-pressure steam plants, unless your water should be very low, must of necessity have larger surfaces all over, and a machine which would operate and give out 100 tons at 40 pounds back pressure, perhaps if put under exactly the same conditions as to temperature and amount of water, and put on 5 pounds back pressure, will not yield anywhere near that tonnage. Consequently the capacity of the machine must necessarily go down with the degrees of heat head. Mr. Torrance, I believe, did not go into the question of costs of apparatus.

Henry Torrance, Jr.—No; I will say that the cost of the low-pressure system is more—it is some 20 or 30 per cent. more.

No. 10.

THE PRACTICAL VALUE OF INDICATING THE AMMONIA COMPRESSOR.

By W. Everett Parsons, New York, N. Y.

(Member of the Society.)

The paper which I have prepared should really be of more interest to operating engineers than to the members of this Society, since it is written more for their information. As I have had considerable to do with the operation of refrigerating machinery, I have realized the lack of knowledge among operating engineers in general in regard to indicator diagrams from ammonia compressors.

Of no class of machinery is harder service required, nor is any subjected to a more severe test than the machinery of a cold storage or ice-making plant.

Too much care cannot be exercised in the construction of such machinery; and the user who buys inferior machinery, because it is cheap, pursues a "penny wise and pound foolish" policy. The efficiency of the best machinery, however, is often seriously impaired in a comparatively short time after it is put in use by the incompetency, carelessness, or neglect of engineers in charge of its operation.

It requires intelligence, forethought, much preparation and eternal vigilance to keep a refrigerating or ice-making plant up to its maximum capacity and highest efficiency during a continuous run, every week, every day and every hour, for a period of four or five months.

To put a plant in condition, in winter or spring, to insure the best results during the warm season, is like preparing for a battle. Not the slightest thing that can affect the operation of the plant should be neglected. As soon as the machinery and apparatus have been put together, after the winter's overhauling and repairs, every part of the plant should be thoroughly tested before the advent of warm weather. You cannot be sure that your joints are all tight unless you test them under pressure. Neither can you be sure that your compressors are in the best possible working order unless the pistons, valves, valve springs, etc., are properly tested.

There is no better means of ascertaining whether the various parts of a compressor are performing their various functions properly than the use of an indicator, such as is used for steam engines. And yet we find a large number of compressors with no connections or rigging provided for attaching an indicator. At a still larger number of plants we find no indicators. There are some places, however, where indicator, connections and rigging are all provided, and yet the operating engineer never uses them. But—most remarkable of all—the majority of chief engineers who operate refrigerating machines not only do not indicate their own compressors but resent the suggestion that someone else do it for them. It must be admitted, however, that the application of an indicator to a compressor often puts an engineer to considerable inconvenience where the necessary attachments are not at hand and prepared for easy adjustment; and, besides, a large number of operating engineers do not know how much may be learned by the careful analysis, study and comparison of various compressor diagrams; nor do they realize that all of the conditions of operating must be taken into account if the object is to detect and locate defects in the internal parts of a compressor by means of such diagrams.

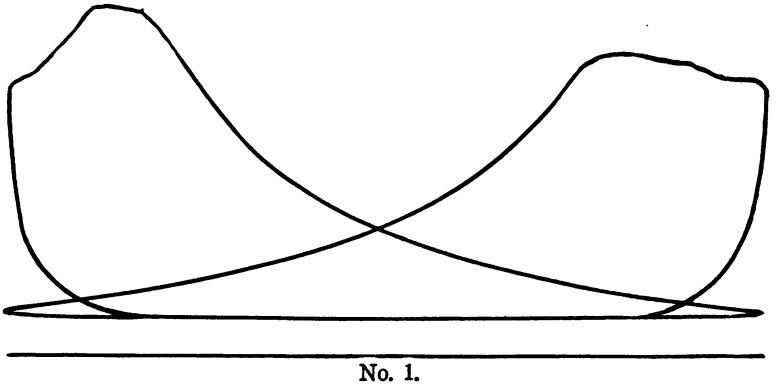
For instance, every part of a compressor may be in perfect operating condition, but indicator diagrams taken from it under various condensing pressures, back pressures, speeds and adjustments of the means of cooling the cylinder will vary in appearance, according to the conditions. These variations often render the diagrams not only worthless but often harmfully misleading to one who depends on only a casual inspection of the diagram in trying to determine whether the compressor is giving the best possible results. But if these diagrams, taken under varying conditions, are properly studied and compared much valuable information can be derived from them, and the conditions that are conducive to the best results may be determined.

The indicator can be made to play an important part in determining the relative merits of the various types and designs of ammonia compressors and of the several methods in practical use for cooling the compressor cylinders. It is my present purpose, however, to confine myself to trying to interest everyone connected with the every-day practical operation of refrigerating machinery in the advantages that may be derived from the intelligent and frequent use of the indicator and its diagram in connection with ammonia compressors.

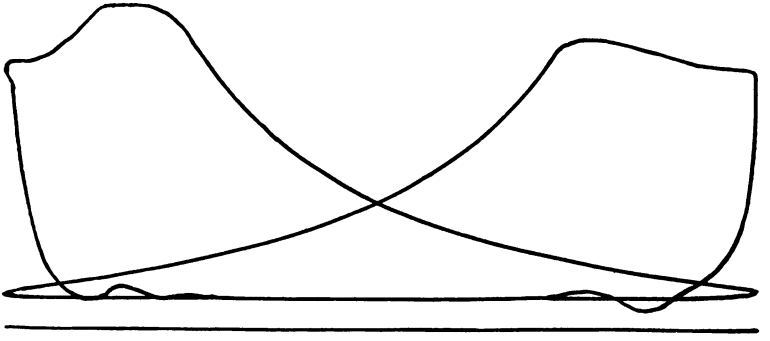
With compressors of different types and designs there are more

or less parts that are subject to derangement and which require proper adjustment from time to time. The piston or any one of the valves may leak, or the valve springs may not be properly adjusted, or the means for cooling the compressor cylinder may not be properly regulated. Any one of these defects can seriously impair the efficiency of the compressor. It is, therefore, the duty of the operating engineer to use every means available to detect such defects. A great many engineers seem to think that so long as their machines can be made to do the work required of them the compressors must be all right. But in many cases refrigerating machines are run at a much higher speed than is necessary to do the work required on account of the impaired efficiency of the compressors, and the coal consumption and the wear and tear of the machine are correspondingly increased. Where no regular record of the revolutions of the machine is kept no comparisons can be made with the original speed, and that the speed is being gradually increased will not be noticed.

Here are some sets of diagrams that show some of the things



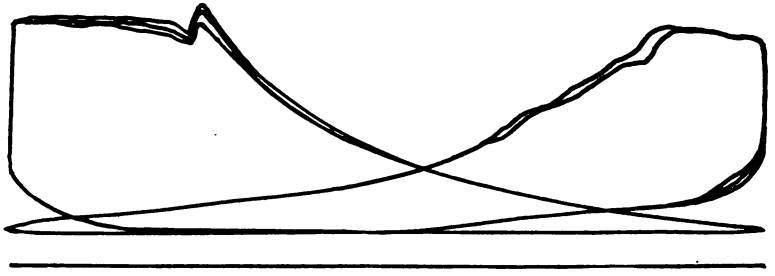
No. 1.



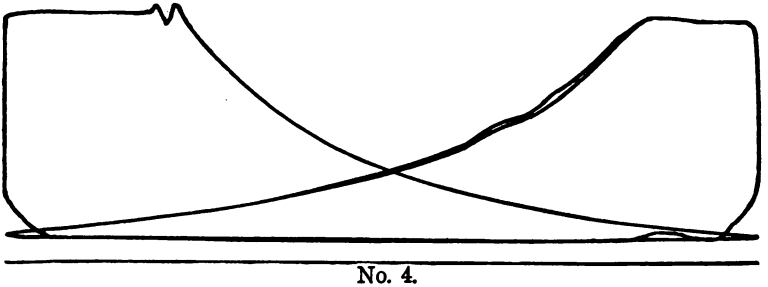
No. 2.

which may be learned from indicating compressors. Sets No. 1 and No. 2 were taken from a horizontal double-acting compressor, which was provided with a water jacket. The engineer, however, was in favor of the wet compression system and made no use of the water jacket. He protested strongly that his compressor was all right and that he did not want it indicated. He was induced, however, to make preparations for attaching an indicator, and was told to operate the compressor and regulate the cooling of the cylinder as he thought best. The set of diagrams No. 1 was then taken. You can imagine the engineer's surprise when he was shown by this means that the discharge valve at head end required a great excess of pressure to open it, that it did not then open wide enough, and that it did not close promptly. It was also demonstrated that he was admitting too much liquid ammonia to his compressor. Set No. 2 was taken some time later, after the freezing back had been reduced until the discharge became hot.

The loss due to clearance, which was about 17 per cent. when No. 1 was taken, was reduced to about 10 per cent. when No. 2 was secured. It was also discovered by means of the indicator that the high-pressure ammonia gauge was indicating about 25 pounds higher than the actual pressure. In consequence of an apparently too high condensing pressure the chief engineer was spending a large sum for additional condensers in order to reduce the pressure.



No. 3.



No. 4.

It would have cost less to have had his gauge tested. Diagrams No. 3 and No. 4 were taken from a double-acting vertical compressor which was being used for ice making. When No. 3 was taken there was so much liquid ammonia entering the cylinder that the discharge was quite cold.

The engineer said he considered it proper to circulate as much liquid ammonia as possible. He mentioned the fact, however, that he did not freeze back quite as hard as his predecessor did. No. 4 was taken after the freezing back had been reduced till the discharge was hot. This convinced the engineer that the refrigerating work done was not always in direct proportion to the intensity of the freezing back. These diagrams showed also that one of the suction valves was leaking badly.

For the benefit of all concerned I would strongly advise that the manufacturers of ammonia compressors should furnish every connection, attachment and convenience that are necessary for the easy and quick adjustment of an indicator to their compressors.

I would urge every engineer operating ammonia compressors to take indicator diagrams from his compressors before shutting down for the winter overhauling and repairs, and also as soon as the machines are in operation again, before the advent of the summer season. Then diagrams should be secured at several times while the compressors are working under their summer loads.

An engineer, in order to understand the value of such diagrams, however, must be able to properly read and understand them. Diagrams from ammonia compressors are much more difficult to read than those from a steam engine, but the engineer who studies to become expert in interpreting them will find himself well repaid for his trouble.

Before closing, I wish to say most emphatically that I would not have anyone draw the inference from the foregoing that ammonia compressors in general are subject to frequent derangements. I would simply call attention to the importance of adopting the best possible means for detecting any defects or derangements that might occur.

DISCUSSION.

Thomas Shipley.—I want to take exception to what the author of this paper says in regard to the indicator. I do not believe that the indicator is the best method of telling what your compressor is doing. I know this from the facts we obtained down in our test plant. The indicator is not in it along with a thermometer on the suction and on the discharge pipes.

In looking up the efficiency of the compressor we cannot tell by the indicator what that efficiency is. I have some indicator cards in my pocket which show a machine handling about 35 pounds of ammonia per ton, and I have got cards of the same machine handling about 25 pounds of ammonia per ton. The efficiency of the compressor, that is, its capacity for handling ammonia, was certainly a great deal more in the case where it was using 35 pounds of ammonia per ton than where it was using but 25 pounds of ammonia per ton; but the cards do not show that. The cards would show the other way.

I believe the author of this paper would say, if he looked at these indicator diagrams, where the compressor was using 35 pounds it was the least efficient; but that is not the fact, because we weighed the ammonia, and we know that it was handling a good deal more ammonia per thousand cubic feet displacement than in the other case; but you cannot tell that with the indicator. Better have thermometers on the suction and on the discharge pipes. I do not consider that the indicator is the best method, nor is it the easiest for the operator to keep tab on what his compressor is doing.

Another thing I want to say is, that in a test where we drilled a one-eighth inch hole through the discharge valve of one of the compressors the temperature of the gas discharged from this compressor was 40 degrees higher than the gas from the other compressor, the thermometer in the discharge pipe showing the effect of a leaky discharge valve at once, whereas with the indicator you would have to plot your curves and go through a lot of monkey business that the ordinary engineer would not have a chance to do, even if he knew how to do it, which he probably would not; and what we want to do is to make machines and equip them with apparatus that an operating engineer can look at, the same as with the gauge, and tell what he is doing, or very near what he is doing, and not have to go through a whole lot of work, which not one in a hundred of them can do.

We do not keep that kind of man as a rule in the engine room. If he knows how to work a planimeter and plot curves correctly he does not hang around the engine room long. I am talking from the standpoint of the manufacturer who has to put the machines in everybody's hands, competent and incompetent, mostly incompetent. Men who are experienced in testing this kind of apparatus do not work long as operating engineers. In any case the thermometers are a great deal better, a good deal safer and more apt to tell you what you are doing than the indicator.

Gardner T. Voorhees.—In Mr. Parsons' paper I notice that he referred to pressure gauges. I want to take the same stand that Mr. Parsons does regarding pressure gauges, and say it is almost invariably my experience that the gauges, the suction gauge and the condenser gauge, are anywhere from a few pounds to 25 pounds off. I think it is usual in practice to find gauges misleading and that they give such results that the engineer is misled into running his machine at a much lower back pressure than is necessary, or into thinking that he is not putting the right quantity of water over his condenser. The gauges should be tested by a gauge tester. If the plant is large enough to afford one of these gauge testers it should be a part of the paraphernalia of the plant, and it should be the duty of the engineer to test these gauges once a month.

I was a little surprised in Mr. Parsons' paper to notice that he said nothing at all of the absolute necessity for plotting the adiabatic line on the indicator card. Any good engineer and any man who is capable of reasoning out any problem in the engine room should be able to look at the indicator card and be able to see if the compressor has too much clearance. He will look at the top of the diagram and see if the discharge valve is too small or if its spring is too strong. These things he may or may not be able to remedy. I see on Mr. Parsons' card that the toe, instead of being sharp, is blunt. This shows that his discharge valve may leak or that something else may be wrong. I have seen some excellent engineers who could not give a reasonable, right or logical interpretation of the indicator card, and I would challenge any engineer to give the proper interpretation of a card without first putting on the adiabatic line to show that the compression of the gas is following the laws it should, and I would say from my experience, from hundreds and hundreds of indicator cards, that with a machine in good condition the compression line will follow the adiabatic curve almost exactly for three-quarters of the stroke.

I want to lay the greatest possible stress on the fact that anyone who takes a card from an ammonia compressor and fails to put on the adiabatic line, and generally the isothermal line also, is not capable of interpreting that card.

The planimeter is a valuable instrument, of somewhat more exact precision than is the method of measuring the ordinates of the card for determining the power.

It is not necessary for an engineer to have a planimeter except to save time, because he can take a scale and measure the heights

of the ordinates and get the mean effective pressure with as great a degree of accuracy as is necessary. The efficiency of the compressor cannot be completely shown from the indicator card alone, but can be closely approximated. I believe that you cannot thoroughly consider just why the efficiency is or is not better or worse unless you have the indicator card, but I do agree that the indicator card will not entirely show the efficiency of the machine.

I notice that Mr. Parsons said that one of his cards showed that the suction valve leaked. I want to ask Mr. Parsons how, from any card that he has, he can positively say that the suction valve leaked without having drawn on the adiabatic line?

W. Everett Parsons.—I suppose I ought to answer that first as it is a direct question, but I prefer to begin with Mr. Shipley. In the first place, I made my paper short because I thought the discussion on it would be worth more than the paper, and I wanted to bring out points from everyone that I could.

Now, in regard to the indicator being the best means of ascertaining the efficiency of the compressor, I did not put it in that way. I say there is no better means of ascertaining whether the various parts of a compressor are performing their various functions properly than by the use of an indicator. I said nothing about efficiency, but about ascertaining whether the compressor was doing its proper work.

In regard to the use of a thermometer, I fully agree with Mr. Shipley that this is a most valuable instrument to be attached to the suction and the discharge of every compressor, and I think it should be placed there. It is more easily used than the indicator, but it does not determine as readily as the indicator whether the valves and the piston are doing their work properly.

In regard to the use of the planimeter, I do not think that for the purpose I had in mind the planimeter is of a great deal of use; it is of more use for other purposes. I would like Mr. Voorhees to again state the point which he raised.

Gardner T. Voorhees.—I may have misunderstood what you said, but I understood you to state that one of those cards indicated a leaky suction valve. I ask you how you deduced that result from any card that you have shown?

W. Everett Parsons.—I would refer to your suggestion that the adiabatic curve should be laid out on every card. That is perfectly true, but I did not attempt to give any instructions at length in regard to interpreting the cards. I only wanted everyone to become interested and to encourage them to study. Their trouble

would be well repaid if they would study and learn how to interpret the cards; and that is why I left the curves out. I could not be sure that the suction valve was leaking unless I laid out the adiabatic curve, simply because the diagrams from the two ends of the cylinder were not alike, for without the adiabatic curve I might have been uncertain whether the discharge valve was leaking on one end or the suction valve on the other. I happened to know that the suction valve was leaking in that case, and I demonstrated it to the engineer at the plant where the card was taken. So I did not have to lay out the curves in order to determine that. Also in that particular type of compressor this peculiarity of the card might have been due to a leak in the piston. There are compressors where the piston is perfectly sealed on its upward stroke, but is not sealed on its downward stroke, and this happened to be the case where this card was taken. I have seen cards from the same type of compressor where a leak at the piston caused a similar difference in appearance in the two diagrams.

Gardner T. Voorhees.—I am gratified by the fact that Mr. Parsons agrees with me. I say that, having given an indicator card, and presumably no other conditions, except the natural conditions that would go with the card, the scale, revolutions and the gauge pressure, etc., it is impossible from an inspection of that indicator card to determine whether or not the suction valve is leaking, or the piston is leaking, or the gasket is blown out, without first laying on the adiabatic curve. I hope that after what has been said here, this point will be driven home to the engineers who may take cards in the future.

Thomas Shipley.—I have a few indicator cards here that I would like to give to Mr. Voorhees and Mr. Parsons, and they can lay out all the curves on them they want to, and if they can tell how much work the compressor is doing—that is, how much ammonia it is handling—then they can do more than I can do or have done with the men associated with our company. My experience with indicator cards taken from ammonia compressors has taught me that they will not show the work a compressor is doing. So it is no use to fool ourselves with indicator cards, so far as capacity is concerned.

When the Ice Machine Builders' Association met and compared notes it dawned upon me that we had no real information or data concerning our business. We each had our own guess, but it was only a guess, for none of us knew just what could be done by a refrigerating machine.

Cards are all right to give the "boys" exercise and show what

is going on inside of the compressor, but for practical use they simply tell us the horse power—that is, in connection with an ammonia compressor, and that is why I spoke of the planimeter. After running tests for nearly two years and a half—the tests are going on now night and day—the only use we make of the compressor indicator cards is to determine the horse power. Of course, should there be a leak in the valves or the piston, the indicator card will show it, provided you have other cards to compare with those that have been taken from the same machine under the same conditions as to speed, suction and discharge pressures, and with the ammonia entering the compressor in the same conditon of saturation. Otherwise the leak would have to be an extraordinary one to show up much on the card, or to be found by anyone except an expert.

During our tests we have found that the thermometers in the suction and discharge pipes tell the tale and sound the warning as to the condition under which the machine is being operated, when an indicator card will not, and it is always ready to do the work without rigging up, and can be read as readily as the pressure gauge.

Mr. Parsons says that he can tell by a twist in the card he has shown that the suction valve leaks. I can show him cards taken from the same compressor, one of which will have that twist and the other will not, the suction valve being exactly in the same condition in each case, the change being the condition or saturation of the ammonia as it enters the compressor. Hence it is not always possible to tell a leak by the card without other investigations.

There are other things to be taken into consideration in connection with the cards Mr. Parsons has shown. He says they are taken off a wet compression machine. Now, we are after work, useful work. Not only in the compressor but from the plant as a whole. In our tests we have found that the efficiency of the evaporating coils is very much increased by being flooded with ammonia, and I don't mind telling you that we find we can get an average heat exchange of from 150 to 200 B. T. U. per degree difference in temperature per square foot per hour under the flooded condition, which is the same condition as prevails when a machine runs wet compression. Whereas, running the same system under the dry compression condition—that is, just freezing out, and bringing the gas back to the compressor in a slightly superheated condition—we only get an average of from 50 to 75 B. T. U. per degree of difference per square foot per hour.

Now, your compressor cards may show up badly when you are running under a wet condition, but you may have to do it because

your evaporating coils may not have sufficient surface or may not be in a proper condition to take up the heat, unless they are flooded. In this case you must put up with a few twists in the cards which an expert would condemn.

The compressor running under a dry condition will show a better card and be more effective, but the other conditions of the plant must be taken into consideration, or the daily output cannot be made by the plant.

Now, in regard to the relative efficiency between wet and dry compression, we added a double-acting horizontal ammonia compressor of the "Vilter" type to the machine we have in our test plant. The double-acting compressor is the same size as the single-acting compressors, each having exactly the same theoretical displacement per revolution.

We have run a great number of tests to determine the relative efficiency of wet and dry compression under the same conditions. And we have found that a compressor running dry compression will, at 15.67 pounds back pressure, do about twice the work per cubic foot displacement that the same compressor will do running under a wet condition, the evaporating coils being operated under the same conditions in each case. Our experiments also show that this difference in efficiency is not constant for the different range of back pressures. It increases as the back pressure lowers, and lessens when it is raised above the pressure given, 15.67 pounds, which corresponds to a zero evaporating temperature. We have not run enough tests as yet at the different back pressures to be able to strike a curve that we are willing to stand by. I will tell you how we kept the evaporating coils flooded while the compressor ran under a dry condition. We connected up a trap or separator to the evaporating coils and arranged it so that the liquid coming over from the coils would be separated from the gas and fed back to the coils by gravity, while the gas went to the compressor. When we wanted to run wet compression we shut out the separating system and allowed the liquid and gas to go over to the compressor, which would run under a wet condition. In this way the evaporating coils were always under the same condition, and a comparison can be made as to the efficiency of the compressor operating under the wet and dry condition.

There has been a great difference in opinion among engineers in our line as to just what is wet compression. I have tried to locate the man who really knows what Professor Linde means by wet compression, and as near as I can get at it, a machine is running wet compression when the discharge gas is at the temperature of satura-

tion due to the high pressure, or pressure at which the ammonia is being condensed.

The usual direction given to the operating engineer is to keep the temperature of the discharge pipe about blood heat. Here is where the thermometer in the discharge pipe does good work. The discharge gas temperature is the only one you can do anything with in a machine running wet compression, for the reason that so long as the suction gas is not superheated you always have the same temperature, no matter how much liquid is coming over.

We have made a number of tests, as I have said, and the one which will interest you most is the one we are running at this time, viz.:

Keeping the work constant;
Keeping the back pressure constant;
Keeping the high pressure constant;
Making the speed of the machine variable;

Running twelve hours wet, then twelve hours dry; running night and day, and keeping it up for two six-day runs—that is, two weeks, except on Sunday. We run in this way, alternating wet and dry condition, to see if the tests will corroborate one another.

You will understand the object of this series of tests was to reproduce a condition which would confront an engineer if he went on a plant where the compressor was running wet compression and attempted to show what saving he could make by changing the plant as I have indicated, viz., keep the evaporating coils operating under a flooded condition, thereby getting their maximum efficiency, and operating the compressor dry compression, thereby getting its maximum efficiency. To do this he would have to put in a separating system between the evaporating coils and the compressor.

The following table will give you an average of about a dozen tests we have made so far:

	Wet Compression.	Dry Compression.
High pressure.....Pounds.	185	185
Back pressure..... "	15.48	15.24
Temperature discharge gas.....	96.52°	249.16°
Temperature suction gas.....	— .335°	1.8°
Revolutions per minute.....	60	44.37
Compressor horse power per ton refrigeration... ...	1.99	1.61
Tonnage by brine.....	21.37	20.6
Minimum brine temperature.....	8.11°	8.55°
Range	5.37	5.22
Pounds ammonia per ton refrigeration.....	35.04	25.41

Now, I do not want to be understood as trying to claim that indicator cards are no good, but I want to call to your attention the fact that thermometers on the suction and discharge pipes, as close as possible to the compressor, will do you more good and be more reliable than indicator cards. Another thing I want to say, and that is, I want to tell you that we found it impossible to test a plant at a given back pressure with a spring gauge. A mercury column is the only thing that should be used on the suction side when a test is being made.

We have had several tests of test gauges that have just come from the makers strung out on a tree connection, and every one of them would show a different pressure after a few hours' work. Not only this, but you cannot get a gauge to register fine enough, whereas with a mercury column it is possible to read to the fraction of a pound.

Another thing. Don't attempt to meter ammonia. You cannot depend upon an ammonia meter. Weigh your ammonia the same as you weigh water going into a boiler.

Why don't the boiler experts use meters when they test boilers? Because they are not accurate enough, even for water. Well, just imagine trying to get a meter that is not accurate enough to measure water to measure liquid ammonia!

So when the expert comes around don't let him pull either a gauge or a meter on you, for with either he can get curves enough to make even himself crazy.

Gardner T. Voorhees.—I want to take the strongest possible stand against the position that generally the indicator cards show nothing but horse power. To make an illustration to show how much more than horse power can be determined from a card: I had an experience with a 200-ton dry compression machine which was not doing the refrigeration that it should. The engineer took a card from the machine, which looked about like the one I have drawn on the board. He brought me the card and said: "Mr. Voorhees, there can't be anything the matter with that machine. That is a perfect card. There is no clearance." Everything about the card looked right. You could figure the horse power. But the card showed that there was something radically wrong with the machine, and I told the owners that the machine was wrong, but they persisted in running the machine for two or three months, until they got Professor Denton to corroborate what I told them. By putting the adiabatic line on the card it showed that the compression line was above the adiabatic line. What was the result? The most natural thing

to assume was that the ammonia gas was at a higher pressure in the cylinder than it should be theoretically and there the theory does agree with the practice. The deduction was that the gas was leaking into the cylinder from the discharge side of the machine. The manager said it was not, because if it was they could hear it leak, etc. But when they took off the cylinder head they found there had been leakage as predicted. There was a gasket between the discharge port and the cylinder. This rubber gasket was blown out. They had been getting little refrigeration because they did not know how to read their indicator cards, and would not believe one who did know how. I want to know whether that card did not show something more valuable than horse power.

Mr. Shipley's statement that gauges are unreliable even more strongly than ever brings out my point that gauges need to be tested. If gauges are no good, how many mercury gauges are there on his plants? If gauges are no good, why does he put them on his plants? They are good, but you have to keep them tested in order to know what you are doing, otherwise you might as well not have them.

Thomas Shipley.—The reason we do not put mercury columns on our machines is because they are only of use when making a test as to how much work that plant will do under a certain back pressure. For instance, if a plant has been guaranteed as a 100-ton plant, and it is desired to prove it. For ordinary use a gauge is all that is needed, but an expert ought to be prepared to attach a mercury column when he goes to make a test.

I want to say again that I do not think that I would take Mr. Voorhees' test with gauges because I am satisfied that he could not tell what he is doing. In fact, when the Ice Machine Builders' Association ran its first test in 1903 it was proven very conclusively that we did not know what we were doing, by getting all kinds of results until we put on a mercury column.

Take the illustration that Mr. Voorhees introduced. If Mr. Voorhees had only had a mercury well in that discharge they would not have had to call in Professor Denton or any other professor. He would have found one compressor was throwing out hot gas, much hotter than the other. He would know that the compressor discharging the hotter gas was lame, and would find the trouble before he could have gotten his indicator rigged up. Just by the temperature, and no matter whether in the suction or discharge pipe, Mr. Voorhees, you will find the leak. If the compressor drives the gas back on the suction side there is the little thermometer telling

the tale, and a man who thinks he can run a wet compression machine and tell what it is doing with his hand on the discharge pipe has a few thinks coming to him. A man who thinks he can tell how much is coming through by hand touch has got a delicate touch, that's all. You must know the amount of liquid that is coming over in your suction pipe to tell what conditions you are even trying to get. It is all right about looking wise, but you are trying to play horse with yourself.

When we put the double-acting compressor in our test plant and began to make tests, we got such a variety of results that I was afraid we did not know how to get the best work out of a machine working under wet compression, so I hired men who knew all about wet compression machines to come down and give us inside information, for I wanted facts. I even went to the president of the company that builds this class of machines, and after showing him what we had done, I asked him if he could run the plant and get anything else out of it. He looked the test plant over, and then said he could not get any better results than we had under the wet condition.

We tried to plot a curve of the work done by the machines under different temperatures of discharge. After we get to a certain point, say about 125 degrees on a discharge, then it heats to about 225 or 250 degrees, and we have to regulate it again, for the simple reason that we have no method of determining how much liquid is coming over. The thermometer shows when the gas is coming over in a saturated condition, or when it is coming over in a superheated condition. You cannot tell how much liquid ammonia is in the suction pipe by any means that I can get hold of.

W. Everett Parsons.—I am very much interested in the discussion of the thermometer question. It is something that has interested me a great deal. I think a thermometer ought to be placed in the suction and discharge of every machine. We can learn a great deal from that and learn it quicker than we can from the indicator, but in writing my paper I wanted to bring out discussion, so I said very positively there was no better means of ascertaining, etc. I made it positive because I thought it would bring out more discussion than if I showed any doubt about it. But at the same time I was speaking about the operating conditions, and I was not discussing the merits of any particular system. I did not want to discuss the merits of the wet or dry systems, but I wanted to get as much information for the operating engineers as I could, and I think the discussion

has brought out a great deal of valuable information for the use of the operating engineers.

Mr. Shipley has stated that when a man has learned how to use the indicator and the planimeter he will leave the engine room. I think we ought to pay operating engineers a little more, so that they will be encouraged to study and learn all they can about the handling of ammonia for refrigerating purposes.

R. L. Shipman.—I have become very suspicious of the indicator for showing leakage in a compressor. I conducted some tests where one cylinder was leaking 20 per cent., making a leakage of 10 per cent. in the machine, and the compression curve came below the adiabatic curve, showing practically a sharp toe on the card, and when the compressor was made to leak about 35 per cent. the compression curve came only a small amount above the adiabatic curve; while in the first place the difference in temperature was about 40 degrees and in the second case it was more than 100 degrees, showing the value of the thermometer over the indicator.

George Berna.—I only wish to compare the question of the thermometer, gauge and indicator to a man being sick and a doctor putting a thermometer under the tongue and feeling his pulse, applying the stethoscope, etc. The indicator would take the place of feeling the pulse, etc. All means employed helping to get a correct diagnosis of the trouble.

Gardner T. Voorhees.—I want to congratulate Mr. Shipley on carrying on some of the most valuable work done since time began, in trying to find out what is actually existing as refrigerating data. The work that he is doing is of the most magnificent kind. I say that such work pays the highest possible compliment to refrigerating engineers, in showing that it takes something more than common observation to know where you are at.

We men who design and consult and make tests, and do this, that and the other, have been saying year after year that the mere fact of putting up a machine and putting up the gauges and saying this, that and the other, is a small part of the game. It should be investigated by men who are competent not only from the practical side but from the theoretical side, and I want to say that if every manufacturer would take up and do this sort of work there would be few questions that would not be absolutely settled. Then the machine builders would not have to guess and look wise, but they would be wise.

W. Everett Parsons.—The remarks of Professor Shipman suggested that I should, in justice to myself, call attention to the fact

that when these cards were taken they were not taken for my own information so much as for the information of the engineers who were operating the plants. I knew that the conditions were wrong; that they were freezing back to their compressor too strongly, admitting too much liquid ammonia, but I desired to show them in some sort of way that could be seen on paper. They did not realize it, but by showing them the indicator cards I was able to demonstrate to them that they could work in a little different way and get better results; that was my object in taking these cards. I had no idea of using them for any other purpose at the time that I took them.

R. L. Shipman.—Certainly the best method of testing the capacity of a dry compression machine is to weigh the liquid ammonia. It is not the difficult problem that it is ordinarily considered, I think. Every plant has drums for storing its supply of liquid ammonia. These drums can be supported by some weighing device, and be provided with flexible connections and arranged in such a way that while one is being filled with liquid from the condensers the other can be supplying liquid to the expansion valves; and, being interchanged at regular intervals, the entire amount of liquid can be weighed for a given length of time, say, five or ten hours, and this, compared with what the machine ought to do, will show whether there is any material amount of leakage in the compressor. This method is far superior to any indicator method and does not require any more expensive apparatus.

Harry M. Haven.—I would ask Mr. Shipley whether thermometers are open to the same objections as gauges?

Thomas Shipley.—We have standard thermometers and interchange them. We have a thermometer for every reading, and put it in the opposite position to show changes, so they correct themselves. That is as close as we can get to it.

I want to say, since Mr. Voorhees tried to throw a few bouquets our way, that our tests were started by the Ice Machine Builders' Association. The plant was put up at its instance, and after the test was started I found how loose we were in the joints. I believed it was good policy to go a little further, and the further I went the more I found we did not know what we were talking about.

Every month or so I have decided to take the plant down and use the space for something else, but I keep on using it. I want to say that the data we have gathered will be made public as soon as I can get the matter in shape so that it can be given out with authority.

I do not care about giving out guesses or data that are not thoroughly corroborated, and that is the reason why I have not given

the results to everybody. To anybody who has asked me for anything I have always tried to give them all the information I could and copies of our tests.

I would be pleased if this Society, if it sees fit, would send a committee down there to try any stunts that it wants to try before I pull the plant out. It might be worth something to all, and the tests your committee make will help check up those we have made, and that would do us that much good. I would be willing to give up the space and the plant.

It takes ten men to make the readings each watch, and I would be willing to furnish the operators of the plant, if the Society sees fit to test anything. The committee could try these things out for itself. Maybe it would be better coming from this Society than from our concern as a manufacturing company.

We do not do anything but make refrigerating and ice-making machines, except a little odd job for a neighbor now and then. I know that the hoodoo of the ice-machine business has gone by. We propose to manufacture anything that will make cold weather with ammonia. Besides our regular single-acting machines, we build double-acting machines, either horizontal or vertical. These machines can all be operated either wet or dry compression. We are also building absorption machines. In other words, we are reducing this business to an engineering proposition, the same as if we were building engines. If a man wants a slide-valve engine you ought to be able to give it to him. If he wants a "Corliss" compound, give him a "Corliss" compound. If he wants a triple expansion, give him a triple expansion. There are uses for all these different kinds of machines.

The trouble has been with ice-machine manufacturers that each company would try to force a customer to take its particular make of machine, no matter what was the best type of machine for his use or the work to be done. I know this is a fact, for I have done it myself and hired other men to do it. We had not been enlightened at that time.

We will have to go into this business from an engineering standpoint. If an absorption machine is the proper thing to put into a place, then the engineer who says it should not go in there is deficient in knowledge. If the conditions are such that a compression machine should go in, then I believe that is the thing we ought to recommend, and I want to say that the company I am trying to steer is prepared to give you a machine for the work it is going to do, and we will build anything that will make cold weather best under exist-

ing circumstances. So we want to be on record as not being hidebound on any particular type of machine.

*W. Everett Parsons.**—In reviewing the discussion of my paper I find that Mr. Shipley said: "I do not believe that the indicator is the best method of telling what your compressor is doing. I know this from the facts we obtained down in our test plant. The indicator is not in it along with a thermometer on the suction and on the discharge pipes." "In looking up the efficiency of the compressor we cannot tell by the indicator what that efficiency is." Further on he says: "I believe the author of this paper would say, if he looked at these indicator diagrams, where the compressor was using 35 pounds it was the least efficient, but that is not the fact." I will say right here that Mr. Shipley had no means of knowing how I would interpret his diagrams.

Further on Mr. Shipley repeats several times that indicator diagrams from a compressor are of practically no use except to determine horse power. He claims that thermometers in the suction pipes and discharge pipes will tell more about what a compressor is doing than will the indicator. He says also that the ordinary pressure gauges are unreliable.

In my paper I said nothing about being able to determine, by means of the indicator, the refrigerating capacity or efficiency of an ammonia compressor. I did say, however, "There is no better means of ascertaining whether the various parts of a compressor are performing their various functions properly than by the use of the indicator."

My paper was intended to apply to ammonia compressors in general, of all types and makes, and was intended to point out the best way to determine the conditions existing in a compressor during its operation when often the person operating the indicator does not know anything beforehand of those conditions.

Mr. Shipley finds fault with the indicator because he cannot determine with it the amount of liquid handled by the compressor, but neither can he do this by means of the thermometer; nor can he tell with the thermometer whether the ammonia coming back to the compressor is saturated or superheated, unless his back pressure gauge is correct; and he says that such gauges are never correct, and that a mercury column cannot be used in ordinary practice.

He says that he could tell by means of thermometers in the discharge pipes of his compressors that one of the discharge valves

* Author's closure under the rules.

was leaking because one thermometer indicated a higher temperature than the other. But suppose someone had drilled a 1/8-inch hole in the discharge valve of each compressor without his knowledge and before he had inserted his thermometers in the discharge pipes, isn't it quite likely that both thermometers would have indicated the same temperature? Would he have discovered so easily by means of thermometers in such a case that the discharge valves were leaking? He doesn't believe in using the sense of touch in order to regulate the amount of liquid admitted into a compressor for cooling it.

Whether the so-called wet compression system is right or wrong some of us have to deal with it at times. Now if we have a double-acting wet compressor, and both discharge valves are leaking about the same amount, and thermometers alone are used to guide the operator, he would look at his thermometer and find the temperatures normal and conclude that everything was all right, whereas he might be admitting a harmful excess of liquid into his compressor. This excess would keep down the temperature in the discharge pipes to the normal, and the operator would not detect anything wrong. He would, in blissful ignorance, hang a few more weights on his engine governor and speed up his machine and possibly be able to make it do the work required in spite of the great losses due to excess of liquid and leaking discharge valves, but at a great waste of steam and increased wear and tear on the machine. Thermometers would, in like manner, fail to detect any trouble in case both suction valves leaked, if the back pressure gauge could not be relied upon.

If the piston of a double-acting compressor leaks, the discharge gas will be of higher temperature than it ought to be; but how would the man with the thermometer tell whether the discharge valves or the piston caused the trouble? An indicator would detect all of these troubles.

I give these as a few illustrations to show that although thermometers are good things to "sound a warning," they may sometimes prove very misleading and would very frequently fail to detect or locate any derangement of the working parts of a compressor.

The thermometers have necessarily to be located outside of the compressors, whereas the indicator gets closer to what is going on inside the cylinder.

No. 11.

REQUIREMENTS OF SMALL REFRIGERATING PLANTS OF LESS THAN ONE TON CAPACITY.

By Martin R. Carpenter, New Brunswick, N. J.

(Member of the Society.)

In discussing the subject of the requirements of small refrigerating plants we will have to consider the matter in a general way only and from several different viewpoints. The main ones are those of the purchaser, or user, and the manufacturer, or seller.

Taking that of the purchaser first, we will find the demand for machines of about 1 ton capacity will come from small butchers in cities who desire the advantage accruing from dry cold storage, and also from those so located that ice is not obtainable or the supply is uncertain. The economy of such plants, compared with the use of ice, ignoring the advantages to be gained by having the storage rooms dry, depends largely upon the cost of ice and cost of power. If the purchaser has power available and does not have to run an engine or motor expressly for operating the machine, the economy will be greater with the machine than with ice; otherwise, when considering the amount of the original investment, depreciation, cost of operating, care and attention, and lastly repairs, ice, under conditions usually existing in cities, will be found the cheaper.

In the above comparison we are considering temperatures of from 38 to 40 degrees. If temperatures of 32 degrees or lower are required, the use of a machine is almost a necessity.

There is another point to bear in mind when considering the sale of machines for use in small markets, and this is the fact that, as a usual thing, a marketman's total investment in fixtures, etc., is only from $400 to $600, and an outlay of from $600 to $1,000 for a refrigerating machine is out of the question. It is evident from this that the sale of small machines in such places will be very limited.

Another source of demand is from hospitals, restaurants, cafés and saloons, and machines of 1 ton refrigerating capacity or less may or may not prove advantageous, depending largely upon the nature of the work to be done; though, on the whole, provided power is not too expensive and extra expense is not entailed in order to secure some attention to the machine, it will, as a usual thing,

prove a good investment, both in the economy over ice for maintaining refrigerated boxes and in having the boxes colder, drier and more sanitary, by preventing the slop and dirt attendant upon the use of ice.

Another case which we should take into consideration is that where a temperature of 30 degrees or less is required. In that case the machine has many advantages, and the demand for this class of work will come from furriers, fish markets, and sometimes from cafés and restaurants. While this demand is not very extensive at the present time, it is gradually growing.

We have been considering the demand for machines of about 1 ton capacity in places where they have to compete with ice. We will now consider the demand at points where ice is not obtainable, or where, if it can be secured, the cost prohibits its use to any great extent.

There are a great many towns of small size, so situated that it is almost impossible to ship ice to them, and, as they are too small to support an ice factory, ice is almost unknown. These towns may have from one to three meat markets; and the method usually followed during hot weather is to kill early in the morning and dispose of the meat within forty-eight hours at the most. This means a limited stock of very tough and unseasoned meat most of the time, and at other times meat that is too well seasoned to be palatable. In such cases the cost of operating a small machine is of secondary importance when the beneficial results are considered.

Another demand comes from contractors' camps. This demand is not of much consequence, because, as a rule, such camps are maintained for a short time only, and it would hardly pay to install a machine for temporary use.

So much for machinery of about 1 ton capacity. We will now consider the demand for smaller machines, down to those of 200 pounds capacity. The demand for these will come from stores and residences in cities, largely as a novelty, and also from country clubs and private residences, so situated that ice is difficult to obtain, but where electric power is available. The use of any other power than electric motors will necessitate too much care and attention, though small gasoline engines can be used, provided someone attends to them with more knowledge of machinery than that possessed by the average servant.

As we have considered in a general way the possible and probable demand for these machines we now consider the

types and designs of machines and outfits necessary in order to meet the requirements of such cases and to make them practical.

In the first place, it is necessary, with some few exceptions, to install as complete an outfit as is required in machines of larger type. They must have all the necessary parts, such as motive power, compressor, condenser, expansion piping, with their necessary valves, etc., and must be so designed and installed that they will require almost no attention, except starting and stopping. This applies, in a great measure, to machines of about 1 ton capacity, and becomes more imperative as the size of the machine increases. The great number of these machines required in isolated localities makes it all the more necessary to have them reliable, for experts in this line are difficult to obtain in such localities without considerable expense and delay. It is necessary also to have them automatic in their control as far as possible; and again, any addition of working parts to effect this renders them just so much more complicated and liable to go wrong, and adds to the difficulty of repairing them when anything is out of adjustment.

One of the points to receive attention in the attempt to produce an automatic control was that of the regulating or expansion valve. One of the earliest attempts was made by a representative concern, which experimented with a device for measuring the liquid. This arrangement consisted of two discs, the lower one stationary and the top one revolving. The lower disc had a port which was connected to the liquid line, and allowed the liquid to feed into a cup or recess in the upper disc. This upper disc revolved at a certain speed, proportioned to the speed of the compressor. The liquid in the cup, or receiver, of the upper disc was carried on around and emptied through another port leading to expansion coils, and the amount of liquid which was supposed to go through was calculated to be within the capacity the compressor could handle. While this was a very ingenious arrangement, not much more can be said of it. Various other attempts to regulate the flow of the liquid have been made in connection wth the expansion valve, principally by means of a diaphragm arrangement, working the valve spindle by the variation of the back pressure. This works satisfactorily, except when the very minute opening through the valve becomes clogged up with some foreign substance, and then the expansion coils are apt to become flooded when the valve first opens, especially if the coils are very cold. This then allows the liquid, or, if not actual liquid, a very heavily saturated gas, to go into the compressor, which often

results in trouble of some kind or other, varying with the different styles of machines.

As far as machines of about 1 ton are concerned, the automatic control of the expansion valve is all that is demanded to relieve the machine of hourly attention. However, in smaller machines, especially those for household use, each working part must be able to care for itself automatically, as these machines will be under the care of persons who, as a usual thing, are totally ignorant of mechanical devices, and the turning of a switch must start and stop the machine.

I am supposing, in the above case, that the plant is so equipped that it is only necessary to run it during working hours, and that some attention will be given to see that the condenser water is kept running, and various other points which need attention will receive it, such as the oiling of the bearings, and the examination of the stuffing box to make sure that it is not leaking, and also that there is sufficient ammonia in the system. I have never heard of any automatic devices to care for such parts and conditions.

There is one machine on the market controlled in almost all its moving parts by automatic devices, worked by electricity and operating through a multiplicity of switches, magnets and rheostats. This equipment is so installed that the machine is started and stopped as the temperature of the refrigerator varies, and also as the pressure in the expansion coils varies. It also has an additional device to stop the compressor should the water supply on the condenser fail. This machine is supposed to run night and day, starting and stopping itself, as the temperature varies, and needs no attention whatever, except to see that there is ammonia in the system and oil on the bearings. What effect it would have on the ability of the machine to continue its work should anything happen to one of those delicately adjusted devices, and just how much of an expert would be required to remedy the difficulty, I am unable to say. However, perfection along these lines is almost absolutely essential to the success of the small machines; and whoever succeeds in devising such controlling devices so they are practical and reliable, when in the hands of a novice, will surely reap a reward, perhaps in riches; it may be fame. Any financial reward will be governed by the ability to install and operate the machines at a cost not out of proportion to the results gained.

Machines of from 1,500 pounds to 1 ton capacity may be installed on the premises by an erecting engineer; those of smaller sizes, from 500 pounds down, can be shipped complete, refrigerator and machinery contained on one base, charged with the medium

and ready to start as soon as water and power are connected. While the larger machine would, as a usual thing, be recharged from a shipping drum, the smaller ones may be arranged so the receiver can be disconnected, and a new one, already filled, connected up in its place, without the necessity of pumping down or blowing out.

One method of installing small machines is to place the expansion coils in a tank of brine, and make no effort to automatically start or stop the machine as the temperature of the refrigerator varies, but allow it to run a number of hours each day, as is necessary to produce results; thus removing enough heat from the brine to enable a practically uniform temperature to be maintained in the refrigerator. The water supply should be so arranged that the act of turning on or off the power would at the same time regulate the water valve. And if, for any reason, the water failed, the power should be automatically cut off and the machine stopped. No matter how automatic and fool-proof, there will come a time when the services of someone with a knowledge of the machine will be required, and this necessity will have to be taken into consideration by a manufacturer who makes an attempt to market his products to any considerable extent.

As electric power is the simplest and easiest to use in connection with these small units, the power companies are showing considerable interest in the development of this type of machinery, and are ready to take up and push the sale of them on their own account—when convinced of their reliability—in order to secure the sale of their surplus power; and, no doubt, it will pay them to keep in their employ someone to look after these machines in a general way, provided there is a sufficient number of them being used in their district. Several large power companies have considered the advisability of leasing and operating these machines at an annual rental, thus relieving the householder of all responsibility or investment.

As regards the cost of operating these small machines, I cannot speak with much authority, as I have not had the opportunity of making any reliable tests. The cost of electric power for the only one that I ever observed was about the same as the cost of ice for the same size box, and gave practically the same temperature.

So far I have said nothing regarding the difficulty of installing these machines to accomplish the work specified. This, of course, is easy in the household refrigerator of about 500 pounds or less, as both the refrigerator and the machine are built in the factory and duplicated in size and design. But when the 1-ton and down to 1,500-pound machines are to be installed some pretty careful calculations

have to be made, and a good deal of judgment displayed, for, as a usual thing, purchasers want the maximum size of room cooled, and don't care to invest much in insulation. This means a very small margin on capacity. Again, these machines are apt to be connected up to a box built for ice, and here we have another difficulty to overcome, due to the fact that the arrangements for the circulation of air when using ice will not be effective when using a machine.

There are outfits now on the market, of a size suitable for household use, using compressors of 200 and 300 pounds capacity, equipped with automatic controlling devices, as has been mentioned, to be driven by belt power, from motor or gas engine, which can be bought, exclusive of power, for $300 or $400.

Just how soon these will come into common use will depend somewhat upon how soon the accomplishments of the cook will include a knowledge of how "to pack the stuffing box," etc.

DISCUSSION.

C. C. Palmer.—Mr. Carpenter certainly has given us a very comprehensive statement, and he certainly has covered very thoroughly the requirements of the small machine. The small machine of the future will not be automatic, in my opinion. It is a mistake to try to produce a machine of that kind.

E. N. Friedmann.—Mr. Carpenter has remarked that some of the electric companies are taking up the handling of small machines. I would like to tell a little experience I had in connection with one of the large electric companies.

An architect was building a private residence in Elberon, N. J., and he had an idea of heating the house with electricity. He consulted me about the matter, and I told him it could be done, but I thought it would be too expensive. He said, "Let the electric company send its engineer over and we will see what he has to say."

We telephoned the company, and it sent a young engineer over. I am sorry I do not know his name, but what I am going to tell you is the absolute truth. This young man was interviewed by the architect for about ten minutes, and the architect then said, "I cannot follow you any more; tell my engineer what you are driving at." He said, "This is my engineer (introducing me). Will you explain to him the machine?"

This young man said, "Why can't we put in a compression ice machine?" I said, "We want to heat the house, not to cool it." He said, "By compressing the ammonia you produce heat. This heat is taken up by water in the condenser. Why can't we take that

water and pump it through the radiators and heat the house with it?" I said, "I don't think the temperature would be high enough." He said, "Of course, if you only pump it over once, but if you keep on you will get enough heat in the water to heat the house."

That goes to show that some of the companies are taking up this question, but it seems to me they have to learn a good deal more about it before they can take it up in an intelligent manner.

M. R. Carpenter.—A Boston company has been experimenting for some three years on a small refrigerating apparatus, and a Philadelphia company is experimenting at the present time. It has machines in operation in about four or five places in Philadelphia; and I think there is another concern in Cincinnati that is also taking it up. They are all very enthusiastic until they run the machines about a month or two.

E. N. Friedmann.—I want to mention a case in Chicago. There was a company formed by the name of The Economic. The idea was to make very small ice machines. It installed them under the same idea as the telephone. It rented them, but did not sell them. Its idea was to send a foreman around every once in a while to keep them in order, but after starting it found it needed a foreman for each machine, and that would not pay, so far as I recollect. That was the first attempt that I know of to put in small machines in a general way. I want to say that if the electric companies take it up they must take it up with a different class of engineers than the one I am familiar with.

No. 12.

Discussion of the Topic—BRINE VERSUS DIRECT EXPANSION IN PLATE ICE-MAKING PLANTS.

Thomas Shipley.—I have been asked to say something on this topic, and I will be as brief as possible. I have had considerable experience with brine plants and practically none with direct expansion plants, so you will please remember that.

Regarding the surface required, and that is one of the principal points that would have to be taken into consideration, I would say that my experience has shown that you require about 250 square feet of freezing surface per ton per twenty-four hours on a brine plant, and, in a direct expansion plant, about 275. I believe that the brine plant is more easy to operate than the direct expansion plant, for the reason that the plant can be operated more continuously under the same conditions. That is, the condition does not fluctuate so easily, and the ice can be made of a more uniform thickness, for the reason that the freezing surface is more effective; that is, the temperature of the freezing surface is more uniform.

In a direct expansion plant the freezing surface that is not backed with the liquid ammonia will have one temperature, and the freezing surface that has gas inside of it will have an entirely different temperature, and the range is considerable.

There is one difficulty, however, with the brine plant, and that is the making of plates that won't leak brine; and I will tell you that I have tried pretty hard to overcome this, and I would not guarantee to make a plate to-day that would not leak. It would cost too much money; we could not sell it. So we have to take that into consideration with the brine plant.

I believe that the displacement per ton for the compressors of a brine plant is less than for the direct expansion plant. I will say, however, that we are making some experiments on a flooded condition of coils, which may change my opinion. If we can keep the expansion coils very nearly flooded with liquid it will make them very efficient and keep the temperature more uniform. One of the difficulties with the direct expansion plant is the ammonia leaks, the expansion coils being subject to such a range of temperatures that they are liable to leak. The loss of ammonia on a direct expansion plant is considerably more than on a brine plant.

David E. Haire.—I have had considerable experience with a number of plate plants, both brine and direct expansion. I can corroborate what Mr. Shipley says, that the brine system is objectionable owing to the plates costing more than the direct expansion plates. I can see no reason why the direct expansion plates cannot be made to freeze as uniform as the brine plates, provided you put in the required number of feet of pipe. I agree with Mr. Shipley that it takes more compressor displacement in the direct expansion than in the brine system.

The most serious objection to the direct system is that it takes closer attention on the part of the engineer, owing to the large number of expansion valves. This system must be carefully watched in order not to freeze up your water storage tanks and convey the liquid ammonia over into the compressor.

Thomas Shipley.—In answer to what Mr. Haire says, that he has to flood the coils to get the benefit, I beg to state that this is what we are trying to accomplish. There is no question about an expansion coil being less efficient if it is filled with gas than if it is filled with liquid. You cannot keep the same temperature if it is partly filled with superheated gas as exists when it is filled with liquid ammonia. The only way is to keep it filled with liquid.

Gardner T. Voorhees.—From investigations of a great many plate plants I am inclined to thoroughly agree with Mr. Shipley, and say that I believe the most economical plant will be the brine plate plant, with the exception of possibly the flooded coil, which is known to me as the accumulator system.

If we use brine we will have to use a slightly lower back pressure than if we use direct expansion. From investigation I find that very few brine plants are running at much better than 10 or 12 pounds back pressure, whereas the direct expansion plants will, some of them, run higher. The accumulator system will run as high as 14 or 16 pounds, but there is the objection of the sensible and insensible leaks of ammonia that come from fittings not under your own control; but I believe the direct expansion plant with the expansion valve at every plate or at every four plates, more or less, is a thing of the past, and that the plate plant of the future will either be the accumulator system, which is the coil full of ammonia, or the brine system with brine coolers.

George Berna.—I would like to ask Mr. Voorhees whether he ever made a test of one of these flooded system plants. It seems that the results have been largely overrated by the parties owning the

plants and those building the machines. An impartial judgment would be very valuable for all.

Gardner T. Voorhees.—I must say that I have never seen a plant that apparently gave such satisfactory results as a plant on the accumulator or full coil system.

Thomas Shipley.—I do not think the plant you refer to is an economical one, for the reason that it takes two 17x34 inch double-acting machines to produce 90 tons of ice. The trouble with the plant is that there is no proper separation, the liquid being brought over as wet as possible. It is an accumulator, but no separator system. It is not what should be called a flooded system, but is one of the approaches to it.

Harry M. Haven.—I should like to ask why it should cost more to make the brine plates tight than it does to make the ammonia coils tight.

Thomas Shipley.—The way to make a brine plate is to make a tank—we made them 4 inches between the plates in the tank—and circulate the brine through that tank. We do not use coils at all.

David E. Haire.—In a direct expansion plant, with an expansion valve to each and every coil, great difficulty was found in operating it. We got too much liquid. We devised a plan of making a combined system, partly can and partly plate, and are getting very good results from this.

Thomas Shipley.—On that subject I will say that we would be pleased to furnish Mr. Haire's company a separator that will eliminate the necessity of the can plant.

David E. Haire.—We have separators on a number of plants which, without question, are as good as can be made. We can separate liquids at a low temperature and still get saturated gas in our compressors.

No. 13.

Discussion of the Topic—IS TOP EXPANSION OR BOTTOM EXPANSION BEST IN CAN FREEZING SYSTEMS?

Thomas Shipley.—Mr. President, I want to say that this subject has some bearing on the flooded coil proposition. My experience has taught me that the best way for expanding ammonia into a coil is to introduce it at the top. If you do that the liquid has a chance to trickle down through all the different coils, whereas if it goes in at the bottom it will go through in slugs; the gas will form back of a slug of the liquid, and you cannot get the efficiency out of the freezing surface. I have tried this by taking tanks in operation and changing them from top expansion to bottom expansion and from bottom expansion to the top.

Gardner T. Voorhees.—I believe that top expansion should be used where there is a tendency to the collection of the aqua ammonia liquor in the coils. If only one expansion coil, or two or three, or possibly four or five have expansion valves to govern them it is possible to feed them from the top satisfactorily. If you have more expansion valves, and if you try to regulate them at the top, you get a great amount of ammonia, or else you do not get much ammonia in your coils and have too much gas. I believe that with anything but the absorption machine you should have bottom expansion valves. I tried to regulate the temperature of gas coming out of thirty-two coils. As soon as we got them steady, or as nearly right as possible, one of them would change.

S. J. Rowe.—I wish to state that there is a plant in this city that runs with twenty expansion coils and with only one expansion valve, which gives an absolutely uniform quantity of liquid to each and every coil. The coils are about 104 feet long, and ten pipes high, and the return on each one of those coils is absolutely uniform. This plant has been in successful operation for about three years, and the distribution of ammonia with one valve and twenty expansion coils is an absolute success. That is top expansion.

A. P. Criswell.—I will say that I have been running plants for the last eight or nine years up to a 100-ton capacity with a single expansion valve, and I never had the least trouble in regulating the ammonia. They are all top feed.

E. N. Friedmann.—In the discussion so far it is assumed that

the coils are vertical, but there is one system where horizontal coils are used. It has given very satisfactory results. It is a very good system to use.

David E. Haire.—Out of about sixteen plants under my supervision there are two in particular that have bottom expansion, and we find it difficult to keep these tanks at an even temperature. We contemplate changing these tanks to top expansion. We have one plant in this city that has six freezing tanks, four of which have top expansion and two of which have bottom expansion. We note considerable difference in the ice that comes from these different tanks.

No. 14.

Discussion of the Topic—PRINCIPAL CAUSE OF NON-CONDENSABLE GASES IN AMMONIA MACHINES.

John C. Sparks.—There are two causes which produce non-condensable gases in ammonia machines.

It is a very well-known fact that one volume of ammonia when it is disassociated takes up exactly twice the space that it did when it was in the form of ammonia. Two volumes of ammonia change into three volumes of hydrogen and one volume of nitrogen. The temperature at which ammonia theoretically disassociates should not often be met with in the ammonia machines, but in some parts of the machines, in isolated spots, it might reach that temperature, and part of the ammonia be disassociated in that way.

If the ammonia is made directly from gas liquor, which it usually is not, there are a good many compounds of ammonia besides ordinary straight, free ammonia gas which may be present. In the gas liquor there are volatile ammonia compounds, such as the three carbonates, and also there are the lighter portions of the coal tar, the phenols and the benzols, which may be present. The non-condensable gases come from two causes, one, that the ammonia is disassociated, and the other, from the impurities in the ammonia itself. By ordinary practical tests one can find out very readily which was the cause of the non-condensable gas, and search can be made to prevent the trouble.

If the non-condensable gas is in the top of the condenser one can very readily find out whether it is hydrogen or nitrogen, or whether there are present any of the usual impurities, and directly that is ascertained one ought to be able to locate the points at which the difficulty occurs.

F. E. Matthews.—Something that has not yet been mentioned in this meeting is the trouble arising from the zinc used for galvanizing condenser coils. I should like to hear something along this line.

No. 15.

Discussion of the Topic—THE BEST METHOD OF REMOVING OIL FROM HOT AMMONIA GAS.

F. E. Matthews.—One is almost tempted to avoid the question presented by saying "Cool the gas." In removing oil from ammonia gas, as in removing moisture from steam, there are two things to work with. One is the inertia of the moving particles entrained in the gas or steam, as the case may be, and the other their cohesive and adhesive properties. The lower the temperature of the ammonia gas the greater these forces, and, consequently, the larger the particles will grow, due to cohesion, and the more easily the oil can be separated from the gas by the combined effects of inertia and adhesion. Hence it seems that there are only two things to do in order to effect the separation of oil from gas; first, to keep the temperatures as low as possible; and, second, since there is less difference between the specific gravities of oil and ammonia gas than there is between those of water and steam, higher velocities must be maintained, the direction of flow must be reversed more abruptly with ammonia than with steam, and the oil, having been thrown out of the gas, must be kept out by being conducted to where it will not again be picked up.

John C. Sparks.—In oil that is used in a refrigerating machine the flash point, the point at which vapor comes off readily, is often sacrificed for the cold test, and it is almost impossible to get an oil that will not give off considerable vapor at 300 degrees F. Oils always give off a good deal of vapor before the flash point. Therefore there is always a great deal of oil in the system, and in regard to taking it away from the gas one can, of course, remove a certain amount by suddenly precipitating it on vapor plates or something of that sort, but that is very unsatisfactory, and the oil will be found to go right through the system, even if all sorts of coke filters and everything else are tried.

No. 16.

Discussion of the Topic—UNDER WHAT CONDITIONS DOES IT PAY TO USE A COOLING TOWER?

O. J. Morris.—The subject of cooling towers is a most important one in my section of the country, because the temperature of the atmosphere is high, much hotter than it is in this section of the country, and water, especially good water, is hard to get. So the question of cooling the water and using it over again becomes a very serious and important one in the refrigerating line, and we have had to use cooling towers in many sections.

Most of the ice plants in Mississippi, Louisiana, Arkansas and Texas (especially in Texas), and Mexico are compelled, owing to the scarcity of water, to use cooling towers of some sort. There are few localities in our section of the country where it would not pay to put in cooling towers; in fact, cooling towers ought to be used throughout that country.

My own experience is that it is a good plan to use two cooling towers; one to cool the hot water from the steam condenser and a separate tower to cool the water from the ammonia condensers. By doing this we get colder water for the ammonia condensers, and require less power for forcing the air through the cooling tower. As a rule we use cooling towers in that section with fans. Take, for instance, a 50-ton ice plant and we will use a cooling tower that will require possibly 6 horse power to operate the fans.

In some cases two towers are built side by side, with a centre crank engine directly connected to a line shaft and a fan on each end of the shaft. One fan is for the hot water tower where the water from the steam condensers is cooled and the other is to cool the water from the ammonia condensers.

To show you the value of cooling towers, especially of one such as I have just mentioned, I know of a plant of 30 tons capacity in Texas, where the great trouble was to get sufficient cooling water, having to depend on an artesian well about 700 feet deep. The water was pumped by an air compressor, and it was a hard matter to get sufficient water from this well to operate the plant. Finally they put in a cooling tower, cooling the hot water from the steam condenser in one tower and the water from the ammonia condenser in the other. The capacity of the plant has since been

increased by putting in another 60-ton machine, and since putting in these towers sufficient cool water is had to run the increased plant, whereas before there was hardly enough water for 30 tons ice capacity.

In many places in Texas we have to go from a thousand to three thousand feet deep to get water, where it is a question of spending $5,000, say, on a deep well, and it is here where the cooling tower comes in. Often it is good business to put in a cooling tower rather than bore additional expensive wells. I do not know what value the cooling tower would have in this section. I do know that we cannot get along without it in the Southwest.

The President.—Is it not true that in Texas, as a rule, the air is much drier than in sections perhaps further north and east, and that a tower for that reason is more effective in your climate?

O. J. Morris.—That may be possible. I can only speak of the efficiency of the cooling tower in my own section, and I say again that we could not get along without such towers in the Southwest.

Albert A. Cary.—There are certain conditions where cooling towers are, unquestionably, excellent investments: First, where there is but little water available; second, where condensing water has to be purchased from a city supply, and, third, where the only available water is so full of impurities that the condenser soon becomes incrusted with a coating of heat insulating materials, thus affecting its efficiency materially.

Edwin Burhorn.—The result of using water in a cooling tower is like that in using water in a steam boiler. The evaporation of the water leaves a certain percentage of solids, which must be blown out at intervals. In the cooling tower it is practically the same thing.

We might say that the question of the desirability of the use of a cooling tower is a financial one entirely. In this part of the country water is expensive, in large plants especially. I know of one case in Washington, D. C., where the cost of the water is about $5,000 a year. With a cooling tower we can save about 90 per cent. of that cost, and that will soon pay the total cost of the tower. We know of a tower in New York City that paid its first cost in the first year. The returns certainly pay well on the original investment. The idea of using the towers I think is a good one, the difficulty in many cases being that where the water is used on steam condensers the final temperature is so high that it cannot be cooled in one tower sufficiently to use it economically on the ammonia condensers. In Philadelphia, where we use two towers, the condi-

tions are favorable for this particular installation. The water runs by gravity from the steam condensers directly into one tower, which reduces its temperature to below 100 degrees, and thence it is pumped to another tower placed directly over the ammonia condensers. This tower further reduces the temperature of the water so that it is practically the same as city water for the use of the ammonia condensers.

Gardner T. Voorhees.—I think the question of cool water is most important. In any ice plant, or in one for refrigerating or cold storage purposes, it should be given first consideration, and I think the question of whether you should use a cooling tower or use the water at your command is one of the first questions that should be passed on before you go to the expense of erecting your plant. I think this is the cause of more plants falling down than any other; and if that question had been taken up it would have brought out the necessary problems which would show that we should not locate our plant in this or that district, because we cannot get sufficient cooling water.

Harry M. Haven.—Has anyone observed bad results from the oxidization of the pipes by the use of a cooling tower?

Albert A. Cary.—Generally speaking, water will have a damaging oxidizing effect when heat is applied to drive out its dissolved air. Take a glass of water and set it in the sun; very soon the interior of the glass will be coated with little bubbles of air. The composition of these bubbles will be found quite different from atmospheric air, which contains about one part of oxygen to four parts of nitrogen. The oxygen and nitrogen in the air are not found in chemical combination, but they form a mechanical mixture, and when air is dissolved in water, on account of the greater solubility of the oxygen, we find more oxygen dissolved than nitrogen, and thus the bubbles of dissolved air driven out of the water by heating are found to contain about one part of oxygen to 1.87 parts of nitrogen, thus increasing the oxidizing capacity of this gaseous compound materially. Warmth and moisture together, existing where these globules appear, hasten the oxidizing effect materially.

F. E. Matthews.—Is this oxidization entirely local or does it affect the entire surface?

Albert A. Cary.—The bubbles of air, rich in oxygen, collect at separated positions of small area and cling quite tenaciously to their selected spots, and they seem to have the power of attracting other newly liberated bubbles of air to themselves. If water is moving

sluggishly over the plate holding the bubbles it does not succeed in dislodging them, quite vigorous circulation being needed to accomplish this dislodgment. The corrosion occurring from this oxidization is commonly known as pitting, and when acting for some time will burrow holes similar in appearance to those which might be made with a dull drill, sometimes entirely perforating the plate.

No. 17.

Discussion of the Topic—IS AMMONIA GAS INFLAMMABLE?

R. L. Shipman.—The question of the inflammability of ammonia is one for chemists to determine rather than for engineers. I have made some investigations myself and am sorry to say, so far as I am concerned, I am not capable of deciding one way or the other. Inflammability is a more or less indefinite term, and probably a more definite statement of the case is, Will ammonia in general or in particular support combustion in the presence of air?

This whole question rests on the amount of thermal energy necessary to decompose ammonia and that produced by the recombining of the liberated hydrogen with the oxygen of the air. On this particular point I have not been able to get definite data. If the latter amount is greater than the former, then ammonia will support combustion; otherwise it will not.

Ammonia is a stable compound and is not capable of absorbing any more of the constituent elements of the air, that is, oxygen and nitrogen; and in order that the constituent elements of ammonia may combine with the different elements of the air the ammonia must first be decomposed, which requires a certain amount of thermal energy.

At about 1,000 degrees Centigrade this decomposition is complete, and then the hydrogen is free to combine with the oxygen, forming water, and the burning of ammonia also forms free nitrogen and some nitric acid, and it is this thermal energy of association which is to be compared with that necessary to disassociate the elements of ammonia.

A common experiment in the burning of ammonia is one usually used to test for leakage in the ordinary refrigerating plant. Take a lighted candle and hold it near where the leak is, and when the flame comes in contact with the ammonia gas a big, yellow flame is produced.

This is from the burning of the gas, but when the taper is withdrawn the yellow flame goes out, showing that the ammonia will not support its own combustion under those conditions in the air.

I made some tests, injecting a jet of ammonia in a gas flame,

and the gas flame will decompose and burn a large amount of ammonia, much larger than there is gas escaping from the gas jet.

I projected a jet of ammonia into a charcoal furnace. When a small amount is going into the charcoal furnace the gas will burn at the top; when a larger amount is injected the gas will cease to burn at the top, but by lighting it with a taper it will burn with a large yellow flame. The peculiarity was that the injection of ammonia did not deaden the fire, as I expected it would, but rather seemed to blow it and increase its energy.

John C. Sparks.—I do not agree with Professor Shipman in his statement that he thinks ammonia decomposes before it burns. One can try very simple tests with ammonia, and although ammonia is inflammable in the usual meaning of the word, it will not support its own combustion in the ordinary atmosphere.

If the atmosphere is enriched a little with oxygen—the ordinary percentage of oxygen in air is about 20—so that it is about 30 per cent., the ammonia will burn and support its own combustion at the temperature of the atmospheric air, proving that the ammonia does burn and is not decomposed first. Under ordinary atmospheric conditions one can persuade ammonia to burn while one holds a light there, but the heat given out is just about the same as the heat of combustion, and, therefore, ammonia will not support its own combustion and cannot, in my opinion, be termed inflammable.

Gardner T. Voorhees.—I believe we can strongly say, as refrigerating engineers, that ammonia, as used in refrigerating machines, is not inflammable.

Thomas Shipley.—Mr. President, you will remember the "clinch" we were engaged in about seven years ago. It took three weeks to try the case, and the jury decided it would not burn.

R. L. Shipman.—(These remarks were made in reply to a statement by Thomas Shipley that he put out a fire with ammonia.) That might have been a case of adding more fuel than there were necessary elements to combine with, thus reducing the whole to a temperature too low for burning. While kerosene oil is very inflammable, it is easy to extinguish a fire with it. If we add too much fuel to the gas engine we get no combustion and the engine stops. So the test mentioned by Mr. Shipley is not sufficient, and the whole question rests on the test of the thermal energy.

D. S. Jacobus.—I made quite a few experiments for the New York Board of Underwriters to determine whether ammonia is inflammable or can be exploded when mixed with air. We constructed a small room and allowed the ammonia to flow into it,

both slowly and quickly, and tried various methods of igniting it. We could make the ammonia burn, but there was no explosion. In some of the experiments a large pile of greasy waste was set on fire and the ammonia was blown over it. When this was done the ammonia burned with a large flame and appeared to increase the activity of the fire. Experiments were tried both with saturated ammonia vapor and with the vapor highly superheated. In all cases the ammonia flame would become extinguished when the igniting flame was removed. The experiments, therefore, indicated that if there is a flame or fire the ammonia in going over it will burn and may increase the flame or fire; on the other hand, ammonia will not burn unless the ammonia gas is kept in contact with some other flame or fire.

John C. Sparks.—I do not think any ammonia would aggravate a flame, because it would exclude the oxygen that you are keeping the fire alight with, and so help put it out.

The President.—It seems to the Chair that the question, "Is Ammonia Inflammable?" might be put in another way, "How Inflammable is Ammonia?"

In the little fracas to which Mr. Shipley referred, which occurred several years ago, the judge decided that we could not perform in open court an experiment which we wished to try. Perhaps the judge was wise; but the experiments which would have been shown were these: The object was to show that ammonia under certain conditions, when touching a light, as a candle or ignited paper, would immediately create a larger flame, which in turn would burn articles ordinarily inflammable, as wood; and the experiment we performed in private, but which owing to the adroitness of counsel we never were able to perform in public, was about as follows:

We took a cylinder of ammonia and, after attaching an expansion valve to it, put it on a chair, placed a pan on the floor, and had a man hold a newspaper above the fount, above the end, say, a couple of feet. Then another man held a lighted taper or newspaper down at the pan, and by putting on not too much or too little ammonia, but showering it down barely white, the ammonia would ignite, if that is the proper term, but certainly a great sheet of flame would immediately develop, starting at the ignited taper below and flaming up sufficiently to ignite the paper above, which was clearly beyond the flame, showing that the ammonia did ignite sufficiently to communicate ignition from one point to another, a considerable distance.

That was the limitation of the experiment, and so far as I can see that is about the limitation of the inflammability of ammonia.

Thomas Shipley.—Since you have admitted that you were on one side and I on the other, I will have to tell what little stunts we did, because we were not letting the other side have all the fun. We went to work and got flour barrels and built up as nice a fire as you would want to see, and we put out the fire with ammonia, as I said, to the jurors' satisfaction. We showed that if we had a drum of ammonia and there was a fire we could put the fire out. So that when we left the courtroom there was no question about ammonia not burning. We used to say every day—"Is she going to burn today, or not?" It took us three weeks to satisfy the jury that ammonia does not burn.

Gardner T. Voorhees.—The experiments did not show that ammonia was inflammable. They showed that hydrogen was inflammable. Broadly speaking, ammonia is not inflammable. It is not a question as to whether ammonia will decompose. We all know it will decompose, but that it is not inflammable I think is admitted.

Thomas Shipley.—Mr. President, you will remember that one of the witnesses said, "Your ammonia was rotten; that is the reason it burned," and that went.

The President.—I may say that we could produce the same results from any ammonia in the market.

Thomas Shipley.—But that beat you, all right.

F. E. Matthews.—Is there an evolution or an absorption of thermal energy as the final result of the disassociation of ammonia into its constituent elements and the subsequent combustion of the hydrogen to form water? The former is undoubtedly an endothermic reaction, the latter an exo-thermic one. Now what I want to know is whether the combined effect of the two reactions is endothermic or exo-thermic. It seems to me that the answer to this question will answer once for all the question whether or not ammonia is inflammable. If endo-thermic, then ammonia is non-combustible; if exo-thermic, it is combustible, and whether or not it will support combustion under any given set of conditions without the addition of outside heat will depend upon whether the heat evolved is sufficient to heat the several gases involved up to the temperatures at which disassociation and combustion will take place.

John C. Sparks.—As a matter of fact, I really do not know whether more heat is given out in the burning of ammonia than is taken up in the disassociation, but I personally do not think there is.

No. 18.

Discussion of the Topic—EXPERIENCE IN THE USE OF BOILER COMPOUNDS IN CAN ICE PLANTS.

John C. Sparks.—The subject of boiler compounds to be used for making water more desirable for boiler feed purposes is one that is largely a matter of personal opinion and experience. The general idea underlying the whole question is the removal of hard and soft scale, which in waters containing a relatively large amount of carbonates and sulphates of calcium and magnesium would form a scale in the boilers and cut down their efficiency by forming partial insulation from the source of heat. In some waters having an acid reaction a boiler compound is added to prevent the pitting and corrosion of the iron and, therefore, to lengthen the life of the boiler.

The various boiler compounds on the market may be divided into two general classes; first, inorganic or mineral compounds, and, second, organic compounds such as tannates, etc. As is well known, the general idea of the efficiency of a boiler compound is that it shall combine with the free carbonic acid present in the water and so precipitate the carbonates of calcium and magnesium, which are only soluble in water containing carbonic acid; that is, they are only soluble in the bi-carbonate form. The secondary reaction is that the sulphates of calcium and magnesium shall be changed to the insoluble carbonates of the same elements and, therefore, be precipitated. All these precipitates are from time to time blown out of the boiler and so gotten rid of. Free mineral or organic acidity is neutralized with an alkali and the action of the acids prevented.

It must be understood that any system of water softening for boiler feed purposes is merely the substitution of a relatively less harmful substance to take the place of a relatively more harmful substance, which is eliminated in the form of a precipitate. It is, therefore, necessary that the exact amount of the boiler compound, no matter what that boiler compound is, shall be added to the boiler feed water, so that there is not an appreciable excess of the boiler compound, as too much of this would have bad effects in the boiler. It is, therefore, necessary that the user of water for making steam in his boilers shall know what his feed water contains and keep a check on the amount of the boiler compound he adds to the water.

I am a great believer in simple factory tests being applied, and one can easily educate an operating engineer so that he can perform all the tests necessary. In the alkaline mineral boiler compounds, which make up at least 80 per cent. of the boiler compounds extensively used, too much of the boiler compound present in the boiler will cause the boiler to prime. Everyone knows exactly what priming is, being caused by the surface tension and limit of elasticity of the water being so increased that it will hold vapor under a greater pressure. In plain English this means that the water will foam, and some of the water in the boiler will be carried over with the steam. An ordinary application of this fact is that a drop of pure water does not have sufficient tension to enable much air to be inclosed in it, but if that surface tension and elasticity is increased this is quickly possible, and the small boy when he blows his soap bubbles adds the soap to the water to increase the surface tension and elasticity to enable the water to have enough surface tension to inclose a relatively large amount of air. If you asked him he probably would not know this, but he does know that he cannot blow bubbles with water without soap, though, perhaps, he might use certain boiler compounds to produce the same effect. It is, therefore, important that there shall not be too much boiler compound used, and although hard and fast rules may be laid down as to exactly the amount of a boiler compound to be used for this specific water under consideration, yet the engineer at the plant should occasionally make some simple tests.

The best test when using alkaline compounds is to run some of the water from the boiler into an ordinary tumbler and add to it a few drops of phenolthalein, which reagent is milky white in the presence of acids and bright crimson red in the presence of alkalies. Supposing he does this and finds the color changed immediately to a bright red, he should then cut down his supply of the boiler compound till on repeated repetition of this experiment the color produced is a pale pink, showing only a trace of alkalies present.

One of the most harmful ingredients present in water is the chloride of magnesium. This salt in the presence of heated iron liberates free muriatic acid, which has a violent corrosive effect on the boiler. The next most harmful salts are sulphates of magnesium and sulphate of calcium, all of which form hard scale; then carbonate of magnesium and carbonate of calcium, both of which form soft scale, and also, of course, any free acidity, or common salt that may be in individual waters, but which is only occasionally met with.

I cannot lay too much stress on the subject of priming in boilers.

Everyone knows the general effect of wet steam instead of dry steam in the steam engine, and also the appearance of ice made from water where the boiler has primed is very marked indeed. Anyone at all familiar with the appearance of ice under various conditions can readily detect the mantle of opaque ice that alkaline salts cause in can ice, and it is a very great detriment to the ice made.

There are many good boiler compounds in the market, most of them composed of alkaline carbonates, borates, phosphates, etc., in various proportions, and then there is a tri-sodium phosphate of which you all know, and then there are many organic compounds which are based on tannates. I have found that most of these boiler compounds, if properly administered, will do all that is claimed for them, and I have also found that in most cases the boiler compound is improperly applied in regard to quantity. I am not referring to the water-purifying apparatus and devices, but to the straight addition of boiler compound to the water in the boiler.

I prefer mineral boiler compounds to organic ones, especially in waters containing a large amount of sulphates.

It is rather difficult to lay down any hard and fast rules as to when a plant should use a boiler compound, but if the total hardness of a boiler feed water should be anything over 8 degrees of hardness, according to the United States standard, the water requires a boiler compound; also it is necessary that engineers be instructed when using boiler compounds to blow out the boiler at frequent intervals, so that the precipitated salts are blown out of the boiler and do not accumulate.

Some two or three years ago a man who was selling a boiler compound was sent to my office. The compound itself was really rather good, but the man knew practically nothing about it. He had a nice speech that he had learned at the office. He said that his company had analyzed every water in the United States, and had taken careful means that the boiler compound should be used in the same quantity for all sorts and conditions of water.

I pointed out that that was hard to do, and the idea of testing on the boiler the amount of compound that should be used was very misleading. He did not seem to know what his boiler compound did when it got in the boiler, but he said that any water could be used if one used that boiler compound in that particular quantity. I asked him why it would not be very nice to use the East River water and a little more of the compound. He said, "Yes; use about twice as much and you will get along very well."

I asked him if he knew anything at all about the compound he

was selling. He said "Yes," but he finally admitted that his real business was selling furniture, and he said he sold boiler compound on the side.

You will often find that the boiler compound is very good, but it is badly put on the market, and the instructions to the engineer are indefinite. The engineer should have some simple method of telling whether he has the proper amount in the boiler, whether it does its work, and that he does not have too much in, and thereby get priming in the boiler.

W. Everett Parsons.—I have had a little experience in using boiler compounds in making can ice. While using them I always had discoloration in the core of the ice, and when I discontinued the use of them this discoloration would disappear. What caused the discoloration I was not able to find out, but, after trying a number of compounds, I carefully avoided them, and used the city water and got along without any compound at all. I would like to hear from others in regard to this subject, because one party who furnished one of the compounds claimed that it could not cause this discoloration. I asked him to get me testimonials from the operators of half a dozen can plants in the United States who were using his compound, showing that they never had any trouble with discoloration of the ice while using his compound..

He named one concern in the ice business which was using a can that was of a square section. I pointed out that in such a block of ice there could be a good many impurities, but they would be entirely closed up in the round core, and one could not see what was in the centre of the core. He did not name any concern that was using his compound and making the standard blocks of ice, 11 inches by 22 inches, in cross section. He finally took the compound away, and I did not use any kind of compound after that.

Albert A. Cary.—The use of the so-called compounds introduced into the boiler with feed water in plants where can ice is made does not differ materially from the use of these compounds in boilers used for other purposes, with but one very important exception, and that exception pertains to the stability of the compounds; or, in other words, the sending over with the steam of volatile or gaseous matter distilled from these compounds, which accompanies the steam to the condenser, and from there this condensed gaseous or volatile matter has a tendency to taint the ice so as to give it a disagreeable taste or an objectionable color.

In my experience with steam plants, which has extended over many years, I have found it imperatively necessary in order to get

good results to keep the interior of the boiler clear from all impurities, and the importance of this subject has led me to install in the laboratory of my chemical associates a very complete equipment for the investigation of boiler feed waters and their treatment, and during this experience I have had occasion to make a pretty thorough study of boiler compounds, and believing that a presentation of the results obtained in this work will be of interest to the Society in connection with this discussion, I beg leave to offer the following description of boiler compounds.

By the majority of steam users anything that is put into a boiler to lessen troubles due to the formation of scale is called a "boiler compound"; and the fact that these various so-called compounds act differently in their endeavor to accomplish their purpose is not as generally understood as it should be by those who persist in their use. Such compounds may be divided into three classes:

1. Those which attack the scale-producing material chemically, and which, acting as reagents, combine with the matter precipitated from the feed water, forming a third substance different from either the original precipitated solids or the "reagent," the theory being that the new substance will not form into a hard, resisting scale, and therefore can be more easily removed by blowing off or by the cleaning tools used after the boiler is "opened up."

2. Those acting mechanically upon the precipitated crystals of scale-making matter soon after they are formed. Such "compounds" are of a glutinous, starchy or oily nature, and become attached to the surface of the newly formed crystals (precipitated from the water), surrounding them as the skin does an orange; and when these crystals fall together they are thus robbed of their cement-like action, which otherwise frequently occurs when they are allowed to come in immediate contact.

3. Those acting both mechanically (as just described) and also as a solvent, the latter action partially dissolving scale already formed, and by this "rotting" effect (as it is often called) preparing the scale for easy removal.

The "compounds" under the first division (which act chemically upon the scale-forming matter) also frequently accomplish this same rotting effect upon scale formed previous to their use. Still other divisions or subdivisions might possibly be made, but the above will suffice for a good general idea of the subject.

Taking up our first division of this subject, we find that the principal ingredients used in such "compounds" are soda ash (or carbonate of soda) and tannin matters, while we sometimes find

caustic soda, sal ammoniac, acetic acid and numerous other active agents which are generally less efficient in their action on the scale-forming matter and more harmful to the boiler and its fittings.

In order to disguise these very cheap chemicals and help the "compound" vendor get big prices for his powder or liquid, whichever it may be, there are often added other substances which generally render the active agents less efficient, and they frequently fall unchanged to the bottom of the boiler with the scale, thus increasing the deposit and aggravating the trouble.

Such added substances include clay, chalk, sand, etc., and sometimes merely coloring matter, such as tobacco juice, iron scraps, lampblack, spent tan, etc.

The principal scale-making impurities precipitated in boilers are carbonate of lime ($CaCO_3$), carbonate of magnesium ($MgCO_3$), sulphate of lime ($CaSO_4$), and indirectly sulphate of magnesium ($MgSO_4$), and although there are generally other precipitates, notice of these alone will be sufficient for the present consideration.

Soda ash is a dry, impure carbonate of soda, from which the pure alkali is afterwards made.

The carbonate of soda (Na_2CO_3) is used to act upon the sulphate of lime and magnesia, forming carbonates of lime and magnesia ($CaCO_3$ and $MgCO_3$) and sulphate of soda (Na_2SO_4).

Leaving this treatment for a moment, it would be well to note that both the carbonate of lime and carbonate of magnesia are held in solution through the presence of carbonic acid gas dissolved in the water, which unites with them and changes the mono-carbonates into bi-carbonates.

The mono-carbonates (or single carbonates) of lime and magnesia are but slightly soluble in water, whereas the bi-carbonates (or double carbonates) are very soluble in *cold* water, and this fact will account for the presence of the large quantities of lime and magnesia in boiler waters as carbonates.

When waters containing the bi-carbonates are heated, the rise in temperature drives off the extra carbonic acid gas and leaves behind the practically insoluble mono-carbonates, which are precipitated.

When a temperature of 180° F. is reached, a considerable percentage of the bi-carbonates is precipitated (as insoluble mono-carbonates), and at 290° F. (a temperature corresponding to 43 pounds gauge pressure) the precipitation is nearly completed, after a thorough boiling.

Scale formed from the mono-carbonate of lime is seldom very

troublesome, if not allowed to accumulate in too large a quantity, nor allowed to remain in the boiler for a long time; while the precipitated mono-carbonate of magnesia gives more trouble, due to the fact that it seldom is found in scale as a mono-carbonate. All the contained carbonic acid (CO_2) is generally lost from the bi-carbonate of magnesia ($MgO(CO_2)_2H_2O$) by the time it forms a crust, leaving behind the hydrate of magnesia ($MgO + H_2O = MgO_2H_2$), which acts as a cement and binds closely together (though not very strongly) whatever precipitated matter it may come in contact with.

This hydrate of magnesia is very fine and light when precipitated and requires a comparatively long time to settle.

Next, turning to the sulphates of lime and magnesia we find them very soluble, dissolving in water direct, without requiring the presence of carbonic acid or any other foreign agent.

The amount of sulphate of lime which can be dissolved in one United States gallon of water at different temperatures may be appreciated by examining the following table:

At 32° Fahr. 120 grains per gallon.
At 95° Fahr. 148 grains per gallon.
At 212° Fahr. 127 grains per gallon.
At 250° Fahr. 9 grains per gallon.
At from 260° to 302° Fahr. it is practically insoluble.

This latter temperature (302°) corresponds to 55 pounds gauge pressure, and therefore, when water is thoroughly boiled at this temperature, practically all of the sulphates will be precipitated. The crystals of sulphate of lime will be found to be long and needle-like, and also very heavy and possessing cement-like qualities, so they fall rapidly, and, mixing with the precipitated carbonates, they bind them together into a hard, resisting mass, difficult to remove with even hammer and chisel, if they form a considerable proportion of the scale.

It is here where the active agent in the compound is supposed to take effect, and when the carbonate of soda is used the sulphates of lime and magnesia are changed into carbonates, which are precipitated and form a scale varying from a more or less porous, friable crust to a "mush" or mud. The sulphate of soda which is also formed by this reaction is extremely soluble, remaining in solution at nearly all boiler temperatures and forming no scale, unless allowed to concentrate, and this is prevented by "blowing off" occasionally.

The tannin matters, referred to above, are obtained from various vegetable sources containing tannic acid, such as certain kinds of sumac, gall-nuts, catechu (or cutch) bark, etc. Tannin is generally combined with soda to form the tannate of soda for use with boiler waters to keep the deposit soft or in suspension. Its action is supposed to be as follows:

The tannate of soda decomposes the carbonates of lime and magnesia as they enter the boiler, and tannates of lime and magnesia are precipitated in a light, flocculent, amorphous form, and are long kept in suspension by the circulating currents of water, until they finally are deposited in a loose, mushy mass in that part of the boiler where the circulating currents are the weakest, or possibly the mud drum.

When the above reaction takes place the carbonate of soda is formed, which reacts with any sulphates that may be present, as has already been described.

The use of tannic acid in the boiler cannot be recommended unreservedly, as it will attack the iron as well as the carbonates (although, of course, more slowly), and anything that will corrode the boiler itself certainly cannot be desirable. To test this, anyone can obtain a few cents' worth of tannic acid from a druggist, and by dissolving the crystals in a glass of water and adding some iron filings a very fair quality of ink can be made, due to the action of this acid on the iron.

In practice, the reaction of caustic soda ($Na_2O_2H_2$) with the sulphates seems to be more active than when the carbonate of soda is used, the probable reaction in a water containing sulphate of lime ($CaSO_4$) and carbonic acid (CO_2) producing caustic lime ($Ca_2H_2O_2$), carbonic acid (CO_2) and sulphate of soda (Na_2SO_4). The carbonic acid used in this reaction results from the precipitation of the mono-carbonates from the bi-carbonates, as has been explained.

The secondary reaction from the result just arrived at is that caustic lime (CaH_2O_2) and carbonic acid (CO_2) form carbonate of lime ($CaOCO_2$) and water (H_2O).

The use of caustic soda may be considered less desirable than the use of the carbonate of soda for several reasons.

In the first place, its presence in excess will cause violent foaming in the boiler, and with this foam often the light precipitated matter in the boiler will be carried along steam pipes into valve seats, gauge glasses, etc. It will also attack and cause corrosion of the brass fittings, and it is also dangerous to handle, owing

to its caustic qualities, burning the flesh painfully wherever it comes in contact.

An excess of carbonate soda may also cause foaming in the boiler, but not as violent as when caustic soda is used.

Sal ammoniac (i. e., ammonium chloride) (NH_3HCl) is most undesirable for use in a boiler, due to the liberation of hydrochloric acid (HCl) following its introduction into the boiler. This acid leaves the boiler in a vaporous form, with the steam, corroding boiler, piping and nearly everything it comes in contact with.

There are other "compounds" falling under this classification which are more satisfactory than those named above, such as bi-sodium phosphate and tri-sodium phosphate, the latter being obtainable in both a hydrous and an anhydrous state. The latter is less bulky and its reaction with the sulphate of lime is as follows: Two parts of tri-sodium phosphate ($2Na_3PO_4$) and three parts of sulphate of lime ($3CaSO_4$) form one part of phosphate of lime ($Ca_3(PO_4)_2$) and three parts of sulphate of soda ($3Na_2SO_4$).

The phosphate of lime, after this reaction, falls, forming a slushy mud, making at the most a very weak crust, while the sulphate of soda remains in solution, as previously described.

The fluoride of sodium (NaF) is another "compound" of known composition, which has also proved satisfactory, especially when much sulphate of magnesia is present; its reaction with the sulphate of lime producing fluoride of lime (CaF_2) and sulphate of soda (Na_2SO_4).

The fluoride of lime precipitated in the boiler behaves much like the phosphate of lime just described, while the remaining sulphate of soda is found in solution, as stated above.

Within the past few years barium compounds have been found very satisfactory agents for treating boiler waters, due to their great solubility, quick chemical reactions, and the great weight of the chemical compounds formed in their combining with the impurities found in most boiler feed waters, which property causes them to fall rapidly to the bottom of the boiler rather than floating for some time upon the surface of the water.

High cost has been the principal reason for restricting the use of these barium compounds, but with a constantly increasing demand the cost has been growing lower, and it now promises, before many years, to become a much used boiler water reagent.

The reactions with barium oxide (BaO), barium hydroxide ($BaOH_2$), and barium carbonate ($BaCO_3$) are very similar to those occurring with the similar compounds of soda, excepting that

the barium reactions are very much quicker than those where soda is used.

Our second division of compounds includes a class of materials which are gradually falling into disuse, due to their proven undesirability. They thicken and foul the water in the boiler and coat its surfaces with non-conducting material, and occasionally the precipitated scale-making matter, along with this class of compound, will obstruct the passage of heat through the boiler plates, so as to cause bagging and burning.

In this class we find slippery elm, ground bones, horns and animals' hoofs, potatoes, dextrine and starch, animal fats and animal or vegetable oils.

As rapidly as the scale-forming crystals are precipitated from the feed water they fall into this sticky cooking fluid and become coated with it, and finally fall to the place of deposit, where they remain in a mushy, separated state until the organic matter chances to be burned out, when they will form into a loose, friable scale.

A surface blow-off or skimming device is most essential to reduce the evil, when this class of compound is used, and the bottom blow-off cock should also be opened very frequently.

The principal substances used for the third class of compounds are petroleum and kerosene.

Petroleum oil has much more of the enveloping quality described under the last (or third) classification than the kerosene. Besides producing this effect on the scale matter, both have an active rotting effect on the scale already formed, the kerosene in this case being superior to the petroleum.

Crude oil should never be used, but a carefully refined oil, which has been deprived of its tar or wax, should be selected for this purpose, as these elements cause the formation of a tough, impervious scale productive of bagged sheets and collapsed flues. Petroleum or kerosene should be fed to the boiler with the feed water, drop by drop, through a sight-feed apparatus similar to those used to feed oil to the cylinders of engines. There are several forms of this apparatus on the market. Under no consideration should large amounts of these oils be fed to a boiler at one time, as it must be remembered that the more volatile portion of the petroleum will be quickly distilled off in the hot boiler, leaving the least efficient portion behind, while the more volatile kerosene will be vaporized very quickly, before it has time to thoroughly mix with the water.

Where hard scale has formed in a boiler, it is most effectually

treated by giving it a coat of petroleum or kerosene, to partially dissolve or rot it. These may be applied with a brush or squirted on, but an easier method of application is to first fill the boiler with water above the line of scale deposit, and then pour the oil on the surface of the water and let the water gradually run out of the bottom of the boiler, thus leaving the oil behind clinging to the whole interior surface.

As stated above, kerosene is the most effective in destroying the tenacity or coherence of this deposited scale, but this method of using either oil is not without attending danger, on account of the explosiveness of the vapor given off; so great care must be taken to have no lights in the vicinity of the boiler under such treatment, as men have been seriously injured by this lack of prudence.

The treatment of feed waters inside of the boiler has been a practice of many years' standing, but in the light of recent progress is not to be commended. A boiler certainly has all that it can reasonably be expected to do when it is generating steam without being called upon to perform the functions of a chemical laboratory.

Everyone knows that when a new boiler is started it "steams lightly," and is most economical in its use of fuel, but generally after it has been in service for some time harder firing is necessary and larger fuel bills appear. Following this reasoning, I would ask if it is not far more sensible to keep the boiler constantly up to its original state of efficiency by preventing the scaling and corrosive agents from entering it, rather than accepting such evils and trying to correct them after they have occurred.

The external method of treating feed water, chemically or mechanically, is being adopted by many progressive plants in this country; and in this, I am sorry to say, Americans are far behind the English, French, Germans, Belgians and Austrians, in whose countries the external treatment has been largely and most successfully practiced for many years.

There are, of course, plants where the internal treatment of feed water is an enforced necessity, owing to surrounding conditions or lack of funds necessary to install apparatus for external treatment, but as such apparatus has invariably proved to be an excellent investment it should receive careful consideration from all steam users.

I now feel that I must add, after these remarks on the nature of boiler compounds, something in the way of warning to the users of boiler compounds. Owing to the unfortunate fact that

boiler users have, as a general thing, been too busy to give this important matter of scale and corrosion a proper amount of study, they have become the victims of more impostors than exist in almost any other branch of trade. The boiler quack comes along with his remarkable boiler compound, fluid or special apparatus, and without the slightest knowledge of the character of the impurities held in your boiler feed water he offers his panacea, with a long list of letters of recommendation, written often by the heads of concerns, who are far better acquainted with the financial end of their business than with the steam plant equipment. These gentlemen generally depend upon what their engineer or other employees tell them. The writer knows of not a few cases where the unscrupulous vendors of certain compounds share their profits with these engineers, firemen or other influential employees, which they can well afford to do, as the stuff they sell seldom costs a fifth of what they get for it.

These unscrupulous people, their methods and their wares, have been "shown up" from time to time in the technical and trade papers, and they have not escaped the well-directed fire of the Hartford Steam Boiler Inspection and Insurance Company.*

They are often very tricky manipulators, able to give an apparent exhibition of the wonderful disincrusting power of their purges. I caught one at one time cracking the scale out of a boiler by blowing it empty of its water under steam pressure, and then flooding it suddenly with cold water. Of course, this sudden contraction caused the scale to crack and fall off, but a boiler maker had a nice little job afterwards in making the boiler tight.

In another case I found that one of these manipulators had about ruined a boiler by first giving it a dose of muriatic acid before introducing his "compound." These are but two examples of the many tricks resorted to.

The best advice I can offer on this subject is: Never use any boiler compound, fluid, powder or whatever else it may be called, unless you know positively just what it is composed of and how it will affect the impurities in your boiler water and the boiler itself.

Many of these quacks pretend to have made a chemical analysis of the water to be treated. This is frequently a mere farce, as the same old compound is trotted out on all occasions. Some submit to their proposed victim what purports to be an analysis of their feed water. Many a time a subsequent bona-fide analysis,

---

* *The Locomotive,* Vol. V, page 59, and Vol XV, page 90.

made by competent chemists, has proved to me the absolute worthlessness of these first supposed analyses.

In the treatment of boiler waters, always start with a careful analysis of the water, made by a competent chemist experienced in this line of work. Next, let an expert in this same line, one of known reputation and who is not in any way interested in any method of treatment, analyze any "compound" fluid or powder that has been offered for treatment of your boiler water. If you are dealing with straightforward people they will tell you the exact composition of their material, which the chemist can verify easily, after which the chemist or expert is prepared to advise you properly.

I have already stated that in can ice plants, where the water delivered from the boiler in the form of steam is finally used for making ice, it is necessary to consider the effect of heat upon compounds used in the boiler, to note whether the temperature attained in the boiler will cause the compounds to deliver objectionable gases or vapors which will affect the taste or clearness of the ice.

To this I might add that it is also necessary to examine the impurities in the water as well, as some of these impurities consist of very unstable compounds, such as magnesium chloride, which are split up by the temperatures found inside of boilers, liberating objectionable gases which accompany the steam to the condenser.

With magnesium chloride, which is very soluble in water, the heat reaction will cause hydrochloric acid to be formed, the vapor from which readily accompanies the steam.

There are some so-called compounds that cause a thick glutinous mass to appear in the water or on its surface, and great priming follows when such a collection occurs in a boiler, and in this water, carried bodily in the steam to the condenser, you will find the actual impurities of the boiler water itself, which will be pretty certain to affect the quality of the ice.

John C. Sparks.—I do not agree with Mr. Parsons in his remark that there seems to be more liability to discoloration in the core of can ice when boiler compounds are used than when they are not used. I do think, however, that a more intelligent use should be made of boiler compounds, as the use of too much compound would make the trouble worse by causing the boiler to prime and bring over iron in the form of insoluble oxide.

It is evident from what Mr. Parsons says that too much boiler compound was used in the cases he mentioned, and I am convinced that a proper use of a suitable compound, prescribed after analyzing a sample of feed water, would entirely prevent this trouble.

In Memoriam.

ROCKWELL KING.

Mr. King, a Charter Member of The American Society of Refrigerating Engineers, died at his home, No. 63 Hawthorne Place, Chicago, Ill., on July 27, 1905. At the time of his death Mr. King was President of the Western Cold Storage Company, of Chicago, and also identified with many other large commercial and industrial institutions of the United States. He was born in Chicago, and died in his fiftieth year.

LIST OF MEMBERS.

*Allen, Philip R. (1905), F. W. Bird & Son, East Walpole, Mass.
*Atwood, J. C. (1905), National Ammonia Company, St. Louis, Mo.
Aue, Joseph E. (1904), Snow Steam Pump Company, Buffalo, N. Y.
§Baer, Alvin Hayes (1905), Frick Company, Waynesboro, Pa.
Ball, P. D. C. (1904), Ice and Cold Machine Company, No. 3003 North Broadway, St. Louis, Mo.
Becker, Victor H. (1904), Grand Pacific Hotel, Chicago, Ill.
Behn, Carl (1904), Buffalo Refrigerating Machine Company, No. 126 Liberty street, New York, N. Y.
Berna, George (1904), Hygeia Ice Company, Ithaca, N. Y.
Bertsch, J. C. (1904), Cascade avenue, West End, Atlanta, Ga.
Block, Louis (1904), Mamaroneck, N. Y.
Borgstedt. Henning N. (1905), No. 1142 Tremont Building, Boston, Mass.
Botchford, Henry J. (1905), No. 544 Tremont Building, Boston, Mass.
*Brownell, C. H. (1905), Washington Court House, Ohio.
Brubaker, Samuel H. (1904), No. 614 Law Building, Indianapolis, Ind.
*Burhorn, Edwin (1905), No. 71 Wall street, New York, N. Y.
Carpenter, M. R. (1904), Triumph Ice Machine Company, No. 610 Baymiller street, Cincinnati, Ohio.
Carpenter, R. C. (1904), Cornell University, Ithaca, N. Y.
Cary, Albert A. (1904), No. 95 Liberty street, New York, N. Y.
*Case, Charles L. (1904), A. Booth & Co., No. 152 East Kinzie street, Chicago, Ill.
Church, Fred B. (1904), No. 10 Bridge street, New York, N. Y.
*Cole, Harold W. (1904), No. 184 Inwood avenue, Upper Montclair, N. J.
*Collins, John Glenn (1904), No. 315 Dearborn street, Chicago, Ill.
Cooper, Madison (1904), Watertown, N. Y.
Criswell, A. P. (1904), Nickerson & Collins Company, No. 315 Dearborn street, Chicago, Ill.
*Croll, Cecil H. G. (1905), No. 2A McFarlane street, Wellington, New Zealand.
Daly, Benjamin F. (1905), No. 277 Broadway, New York, N. Y.
De Hart, Jr., John S. (1904), Isbell-Porter Company, No. 46 Bridge street, Newark, N. J.
De Kinder, J. J. (1904), Girard Building, Philadelphia, Pa.
Dickerman, Charles (1904), Twenty-sixth street and Susquehanna avenue, Philadelphia, Pa.
*Ely, James (1905), Hohmann & Maurer Manufacturing Company, No. 85 Chambers street, New York, N. Y.
*Everett, Edward (1905), No. 41 Park row, New York, N. Y.
Flocke, Frank J. (1904), No. 1027 Union avenue, New York, N. Y.
Frick, Ezra (1904), No. 2 East Third street, Waynesboro, Pa.
Friedmann, Edward N. (1904), No. 17 Battery place, New York, N. Y.
*Fentress, R. B. (1905), Norfolk, Va.
Frantz, Samuel R. (1905), Frick Company, Waynesboro, Pa.

*Glover, J. G. (1905), No. 186 Remsen street, Brooklyn, N. Y.
Goosmann, J. C. (1904), No. 911 Schiller Building, Chicago, Ill.
§Greene, Van Rensselaer H. (1905), No. 49 West Sixty-eighth street, New York, N. Y.
Gueth, Oswald (1904), No. 5504 Fifteenth avenue, Brooklyn, N. Y.
*Haire, David E. (1905), American Ice Company, Sixth and Arch streets, Philadelphia, Pa.
Hargreaves, William (1905), No. 510 Candler Building, Atlanta, Ga.
*Hart, Jr., B. Franklin (1905), No. 143 Liberty street, New York, N. Y.
Haven, Harry M. (1904), No. 3 Boston street, Somerville, Mass.
*Herst, Franklin H. (1905), Pennsylvania Cold Storage and Market Company, Twenty-ninth and Market streets, Philadelphia, Pa.
*Hill, Walter L. (1905), Eastern Cold Storage Company, No. 28 North street, Boston, Mass.
Hiller, N. H. (1904), Carbondale Machine Company, Carbondale, Pa.
Holden, D. L. (1904), Hanover Bank Building, New York, N. Y.
Jacobus, D. S. (1904), Babcock & Wilcox Company, 85 Liberty street, New York, N. Y.
Jenks, L. Howard (1904), Frick Company, No. 39 Cortlandt street, New York, N. Y.
Krum, Charles L. (1904), Western Cold Storage Company, No. 39 North State street, Chicago, Ill.
Larsen, John M. (1904), Larsen-Baker Ice Machine Company, Omaha, Neb.
Levey, John (1904), National Machine Works, Sheffield and North avenues, Chicago, Ill.
Louis, J. Shipman (1904), No. 610 Baymiller street, Cincinnati, Ohio.
*McCarthy, George L. (1904), Floor A, Produce Exchange, New York, N. Y.
*McDaniel, Homer (1905), Sheriff Street Market and Storage Company, Cleveland, Ohio.
*McKinney, J. G. (1905), Box 213, Los Angeles, Cal.
*McPartlin, Stephen E. (1905), No. 304 Great Northern Building, Chicago, Ill.
Manns, W. H. (1904), No. 219 West Second street, Waynesboro, Pa.
*Markel, Emerich J. (1905), No. 611 Howard avenue, New Haven, Conn.
*Marshall, Lewis C. (1905), L. C. Marshall & Co., No. 220 Broadway, New York, N. Y.
Matthews, F. E. (1904), Automatic Refrigerating Company, No. 630 Capital avenue, Hartford, Conn.
Meltzer, Arthur (1905), Frick Company, No. 613 H. W. Hellman Building, Los Angeles, Cal.
*Morgan, W. Fellows (1905), Arch 5, Brooklyn Bridge, New York, N. Y.
Morris, O. J. (1905), No. 360 Main street, Dallas, Tex.
Neff, Peter (1904), The Arctic Ice Machine Company, Canton, Ohio.
*Nickerson, J. F. (1904), No. 315 Dearborn street, Chicago, Ill.
Nordmeyer, L. C. (1904), Granite Block, St. Louis, Mo.
Nottberg, William (1905), No. 3313 St. John avenue, Kansas City, Mo.
*O'Conner, Martin J. (1905), No. 1622 Eighth avenue, Brooklyn, N. Y.
Oderman, E. H. (1905), Frick Company, Waynesboro, Pa.
Palmer, C. C. (1904), Railway and Stationary Refrigerating Company, Room 1310, No. 11 Pine street, New York, N. Y.
Parsons, W. Everett (1904), No. 12 Bridge street, New York, N. Y.

Penney, Edgar (1904), Newburgh Ice Machine and Engine Company, Newburgh, N. Y.
Phillips, Ellis L. (1904), No. 45 Broadway, New York, N. Y.
Pilsbry, F. W. (1904), Suite 1060, Monadnock Block, Chicago, Ill.
*Quigley, James Edwin (1905), Twenty-third street and river, Pittsburg, Pa.
*Redway, A. J. (1905), Mitchell Building, Cincinnati, Ohio.
*Reid, Walter C. (1904), No. 32 East Forty-second street, New York, N. Y.
*Reilly, James P. (1905), No. 17 Battery place, New York, N. Y.
*Robinson, W. T. (1904), Pennsylvania Cold Storage and Market Company, Twenty-ninth and Market streets, Philadelphia, Pa.
Roelker, H. B. (1904), (Vice-President 1905), 41 Maiden lane, New York, N. Y.
*Ross, William H. (1904), A 9, Produce Exchange Annex, New York, N. Y.
Rowe, Samuel J. (1904), No. 39 Cortlandt street, New York, N. Y.
*Salkeld, H. F. (1905), No. 525 West street, New York, N. Y.
Schadek, Edward W. (1905), Ruemmeli-Dawley Manufacturing Company, No. 3900 Chouteau avenue, St. Louis, Mo.
Schmidt, Louis M. (1904), No. 76 New Park street, West Lynn, Mass.
*Serrill, Horace P. (1905), No. 411 North American street, Philadelphia, Pa.
*Smart, John Montgomery (1905), American Cold Storage and Shipping Company, Produce Exchange Annex, New York, N. Y.
Smith, Edmond J. (1905), Memphis Machine Works, Memphis, Tenn.
Shipley, Samuel J. (1904), Samuel J. Shipley & Co., No. 18 Park place, New York, N. Y.
Shipley, Thomas (1904), York Manufacturing Company, York, Pa.
Shipman, R. L. (1905), No. 240 Hazen street, Ithaca, N. Y.
Siebert, Alfred (1904), St. Louis, Mo.
Starr, John E. (1904), (President 1905), Starr Engineering Company, No. 258 Broadway, New York, N. Y.
Thompson, Edgar W. (1905), Boyd's Ice Factory, Bombay, India.
*Tinker, Henry W. (1905), Quincy Market Cold Storage and Warehouse Company, No. 41 Richmond street, Boston, Mass.
Torrance, Jr., Henry (1904), Carbondale Machine Company, No. 141 Broadway, New York, N. Y.
*Tough, L. M. (1905), No. 2311 North Charles street, Baltimore, Md.
Trautwein, Alfred P. (1904), Carbondale Machine Company, Carbondale, Pa.
*Turner, Charles L. (1905), No. 411 North American street, Philadelphia, Pa.
*Van Valkenburgh, Ralph D. (1905), Hudson, N. Y.
Vesterdahl, Karl E. (1904), No. 95 Liberty street, New York, N. Y.
Vogt, Henry (1904), Henry Vogt Machine Company, Louisville, Ky.
Vollmann, Carl W. (1904), Coristine Building, Montreal, Canada.
Voorhees, Gardner T. (1904), Engineers' Club, No. 574 Fifth avenue, New York, N. Y.
Voss, Bernhard (1904), No. 242 East 122d street, New York, N. Y.
Wait, John C. (1904), No. 220 Broadway, New York, N. Y.
Wegemann, Karl (1904), No. 258 Broadway, New York, N. Y.
*Werliin, Louis (1905), No. 2815 Gray's Ferry road, Philadelphia, Pa.
*Whelan, Robert A. (1904), A. Booth & Co., No. 152 East Kinzie street, Chicago, Ill.
White, Frank H. (1904), Nonpareil Cork Works, 521 Coristine Building, Montreal, Canada.

Williams, Llewellyn (1904), United Fruit Company, No. 131 State street, Boston, Mass.

Wills, James (1904), No. 161 Chambers street, New York, N. Y.

§Wittemann, Rudolph W. (1905), Wittemann Brothers, Walcott, Sullivan and Ferris streets, Brooklyn, N. Y.

Wolf, Jr., Fred W. (1904), Fred W. Wolf Company, No. 139 Rees street, Chicago, Ill.

Wolf, Otto C. (1904), No. 1025 Arch street, Philadelphia, Pa.

Woods, Arthur R. T. (1905), Spring grove, Town row, West Derby, Liverpool, England.

Woodcock, Willard J. (1905), No. 19 Clifton place, Brooklyn, N. Y.

* Associate Member.
§ Junior Member.
Names without reference marks are Members.
Figures in parentheses ( ), as (1904), immediately following the name, denote year of admission.

INDEX TO VOLUME I.

PAGE.

Absorption Machines, Economy of Combined Compression and..... 126
Amendments Proposed to Constitution and By-Laws..... 27
Ammonia Compressor, The Practical Value of Indicating the..... 137
Gas, Best Method of Removing Oil from Hot..... 170
Gas Inflammable? Is..... 175
Machines, Principal Cause of Non-Condensable Gases in..... 169
Annual Meeting, Proceedings of the First..... 19
Banquet, The..... 34
BERNA, GEORGE, Discussion, The "Plate" System and the "Can" System.. 66
Discussion, The Practical Value of Indicating the Ammonia Compressor 152
Discussion, Brine vs. Direct Expansion in Plate Ice-Making Plants.. 165
Best Method of Removing Oil from Hot Ammonia Gas..... 170
BLOCK, LOUIS, Discussion, Pipe Line Refrigeration.....49, 50
Discussion, The "Plate" System and the "Can" System.....62, 64, 65, 66
Discussion, The Refrigeration of Perishable Food Products.77, 78, 79, 80
Discussion, The Transportation of Fruit in Refrigeration..... 91
Discussion, The Evaporator and Its Use in the Manufacture of Can Ice.....105, 106, 107, 108, 109, 110, 111
The Evaporator and Its Use in the Manufacture of Can Ice..... 102
Boiler Compounds in Can Ice Plants, Experience in the Use of..... 179
Bottom Expansion Best in Can Freezing Systems? Is Top Expansion or 167
BRIGGS, JOHN N., Discussion, The "Plate" System and the "Can" System. 69
Brine vs. Direct Expansion in Plate Ice-Making Plants..... 164
BURHORN, EDWIN, Discussion, Under What Conditions Does It Pay to Use a Cooling Tower?..... 172
By-Laws and Constitution..... 5
By-Laws, Manner of Amending the..... 28
Can Freezing Systems? Is Top Expansion or Bottom Expansion Best in 167
Ice Plants, Experience in the Use of Boiler Compounds in..... 179
Ice, The Evaporator and Its Use in the Manufacture of..... 102
System, Elements Governing the Selection of the "Plate" System and the..... 55
Carbonic Acid Refrigerating Machine, J. C. Goosmann..... 112
CARPENTER, MARTIN R., Requirements of Small Refrigerating Plants of Less than One Ton Capacity..... 157
Discussion, Requirements of Small Refrigerating Plants of Less than One Ton Capacity..... 163
CARY, ALBERT A., Discussion, The Evaporator and Its Use in the Manufacture of Can Ice.....107, 109, 110
Discussion, Under What Conditions Does It Pay to Use a Cooling Tower? 172, 173
Discussion, Experience in the Use of Boiler Compounds in Can Ice Plants 182

PAGE.
Charter Members, Membership Certificates of..... 25
Cold Storage Requirements for the Refrigeration of Perishable Food Products, W. T. Robinson..... 71
Compression and Absorption Machines, Economy of Combined..... 126
Compressor, The Practical Value of Indicating the Ammonia..... 137
Constitution and By-Laws..... 5
Cooling Tower? Under What Conditions Does It Pay to Use a..... 171
Council, The, Report of, for 1905..... 22
CRISWELL, A. P., Discussion, The "Plate" System and the "Can" System 63
Discussion, Economy of Combined Compression and Absorption Machines 130, 133
Discussion, Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?..... 167
Direct Expansion vs. Brine in Plate Ice-Making Plants..... 164
Does a 100-Ton Ammonia Compression Plate Ice-Making Plant or a 100-Ton Absorption Plate Ice-Making Plant Equal in Economy a 50-Ton Compression Machine in Combination with a 50-Ton Absorption Machine, Using the Exhaust Steam of the Compression Machine for Operating the Absorption Machine? Henry Torrance, Jr..... 126
Economy of Combined Compression and Absorption Machines..... 126
Elements Governing the Selection of the "Plate" System and the "Can" System, Edgar Penney..... 55
Emblems, Description of the, of the Various Grades..... 25
Evaporator and Its Use in the Manufacture of Can Ice, Louis Block.... 102
Experience in the Use of Boiler Compounds in Can Ice Plants..... 179
Fabrics and Furs in Cold Storage..... 95
Finance Committee, Report of..... 23
Food Products, Cold Storage Requirements for the Refrigeration of Perishable 71
Freezing Systems? Is Top Expansion or Bottom Expansion Best in Can 167
FRIEDMANN, E. N., Discussion, Requirements of Small Refrigerating Plants of Less than One Ton Capacity.....162, 163
Discussion, Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?..... 167
Fruit in Refrigeration, The Transportation of..... 82
Furs and Fabrics in Cold Storage, Walter C. Reid..... 95
Gases, Non-Condensable, in Ammonia Machines, Principal Cause of..... 169
GOOSMANN, J. C., The Carbonic Acid Refrigerating Machine..... 112
GREENE, V. R. H., Discussion, Pipe Line Refrigeration.....50, 51
HAIRE, DAVID E., Discussion, Brine vs. Direct Expansion in Plate Ice-Making Plants.....165, 166
Discussion, Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?..... 168
HAVEN, HARRY M., Discussion, Pipe Line Refrigeration.....52, 53
Discussion, Brine vs. Direct Expansion in Plate Ice-Making Plants.. 166
Discussion, The "Plate" System and the "Can" System..... 66
Discussion, The Practical Value of Indicating the Ammonia Compressor 153
Discussion, The Refrigeration of Perishable Food Products..... 80

HAVEN, HARRY M.— PAGE.
Discussion, The Transportation of Fruit in Refrigeration..... 92
Discussion, Under What Conditions Does It Pay to Use a Cooling Tower? 173
Ice, Can, The Evaporator and Its Use in the Manufacture of..... 102
Ice-Making Plants, Plate, Brine vs. Direct Expansion in..... 164
Ice Plants, Can, Experience in the Use of Boiler Compounds in..... 179
Plants, Plate, Economy of Combined Compression and Absorption.. 126
Incorporation, Date of, of the Society..... 25
Indicating the Ammonia Compressor, The Practical Value of..... 137
Invitation from York Manufacturing Company and Thomas Shipley to Use Test Plant..... 32
Is Ammonia Gas Inflammable?..... 175
Is Top Expansion or Bottom Expansion Best in Can Freezing Systems? 167
JACOBUS, D. S., Discussion, Economy of Combined Compression and Absorption Machines..... 133
Discussion, Is Ammonia Gas Inflammable?..... 176
JENKS, L. HOWARD, Discussion, The Evaporator and Its Use in the Manufacture of Can Ice.....108, 109
KING, ROCKWELL—In Memoriam..... 192
Resolutions on Death of..... 32
LOUIS, J. SHIPMAN, Discussion, Economy of Combined Compression and Absorption Machines..... 134
MATTHEWS, F. E., Discussion, Principal Cause of Non-Condensable Gases in Ammonia Machines..... 169
Discussion, Is Ammonia Gas Inflammable?..... 178
Discussion, Best Method of Removing Oil from Hot Ammonia Gas. 170
Discussion, Under What Conditions Does It Pay to Use a Cooling Tower? 173
Members and Guests Attending Banquet, List of..... 34
and Guests Attending First Annual Meeting, List of..... 33
List of..... 193
New, 1905..... 21
Membership Certificates of Charter Members..... 25
MORRIS, O. J., Discussion, Under What Conditions Does It Pay to Use a Cooling Tower?.....171, 172
Nominating Committee for 1905..... 25
Officers, 1904-1905..... 3
Officers, 1905-1906..... 4
Oil, Best Method of Removing, from Hot Ammonia Gas..... 170
Organization Meeting, Minutes of..... 20
PALMER, C. C., Discussion, Requirements of Small Refrigerating Plants of Less than One Ton Capacity..... 162
PARSONS, W. EVERETT, Discussion, Pipe Line Refrigeration..... 49
Discussion, Experience in the Use of Boiler Compounds in Can Ice Plants 182
Discussion, The "Plate" System and the "Can" System.....67, 68, 69
Discussion, The Practical Value of Indicating the Ammonia Compressor 144, 151, 152, 155
The Practical Value of Indicating the Ammonia Compressor..... 137

PAGE.

PENNEY, EDGAR, Discussion, Economy of Combined Compression and Absorption Machines....133, 134
Discussion, Pipe Line Refrigeration....51, 52
Discussion, The Evaporator and Its Use in the Manufacture of Can Ice....106, 107, 108, 109
Discussion, The "Plate" System and the "Can" System, 62, 63, 65, 66, 67, 68, 69
Elements Governing the Selection of the "Plate" System and the "Can" System.... 55
Pipe Line Refrigeration, John E. Starr.... 41
Plate Ice-Making Plants, Brine vs. Direct Expansion in.... 164
Ice Plants, Economy of Combined Compression and Absorption.... 126
System and the "Can" System, Elements Governing the Selection of the.... 55
POWELL, G. HAROLD, Discussion, The Transportation of Fruit in Refrigeration....89, 90, 91, 92
The Transportation of Fruit in Refrigeration.... 82
Practical Value of Indicating the Ammonia Compressor, W. Everett Parsons.... 137
President Starr's Address.... 37
Principal Cause of Non-Condensable Gases in Ammonia Machines.... 169
Proceedings of the First Annual Meeting.... 19
Refrigerating Machine, The Carbonic Acid.... 112
Plants of Less than One Ton Capacity, Requirements of.... 157
Refrigeration of Perishable Food Products, Cold Storage Requirements for the.... 71
Pipe Line.... 41
REID, WALTER C., Discussion, Furs and Fabrics in Cold Storage.... 101
Furs and Fabrics in Cold Storage.... 95
Requirements of Small Refrigerating Plants of Less than One Ton Capacity, Martin R. Carpenter.... 157
Resolution Recommending Appropriation by Congress for Experimental Cold Store.... 30
Resolutions on Death of Rockwell King.... 32
ROBINSON, W. T., Cold Storage Requirements for the Refrigeration of Perishable Food Products.... 71
Discussion, Cold Storage Requirements for the Refrigeration of Perishable Food Products....76, 77, 78, 79, 80
Discussion, Pipe Line Refrigeration....52, 53, 54
Discussion, The "Plate" System and the "Can" System....62, 63, 65
Discussion, The Transportation of Fruit in Refrigeration.... 91
ROWE, S. J., Discussion, Economy of Combined Compression and Absorption Machines.... 135
Discussion, Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?.... 167
Discussion, The "Plate" System and the "Can" System.... 66
Seal of the Society, Description of the.... 25
SHIPLEY, THOMAS, Discussion, Brine vs. Direct Expansion in Plate Ice-Making Plants....164, 165, 166
Discussion, Economy of Combined Compression and Absorption Machines.... 134

SHIPLEY, THOMAS— PAGE.
Discussion, Is Ammonia Gas Inflammable?....176, 178
Discussion, Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?.... 167
Discussion, The Evaporator and Its Use in the Manufacture of Can Ice 105, 106
Discussion, The "Plate" System and the "Can" System....61, 62
Discussion, The Practical Value of Indicating the Ammonia Compressor....141, 145, 150, 153
SHIPMAN, R. L., Discussion, Economy of Combined Compression and Absorption Machines....130, 131, 134, 135
Discussion, Is Ammonia Gas Inflammable?....175, 176
Discussion, Pipe Line Refrigeration.... 50
Discussion, The Evaporator and Its Use in the Manufacture of Can Ice 110, 111
Discussion, The Practical Value of Indicating the Ammonia Compressor 152, 153
Discussion, The Transportation of Fruit in Refrigeration....90, 92
SPARKS, JOHN C., Discussion, Best Method of Removing Oil from Hot Ammonia Gas.... 170
Discussion, Experience in the Use of Boiler Compounds in Can Ice Plants 179, 191
Discussion, Is Ammonia Gas Inflammable?....176, 177, 178
Discussion, Principal Cause of Non-Condensable Gases in Ammonia Machines 169
Discussion, The "Plate" System and the "Can" System....63, 65, 66
STARR, JOHN E., Discussion, Economy of Combined Compression and Absorption Machines....132, 133, 135, 136
Discussion, Furs and Fabrics in Cold Storage.... 101
Discussion, Is Ammonia Gas Inflammable?....177, 178
Discussion, Pipe Line Refrigeration....47, 48, 49, 50, 51, 52, 54
Discussion, The Evaporator and Its Use in the Manufacture of Can Ice.... 110
Discussion, The Refrigeration of Perishable Food Products.... 77
Discussion, The Transportation of Fruit in Refrigeration....89, 92
Discussion, Under What Conditions Does It Pay to Use a Cooling Tower? 172
Pipe Line Refrigeration.... 41
Tellers of Election of Membership, Report of.... 21
of Election of Officers, Report of.... 28
Top Expansion or Bottom Expansion Best in Can Freezing Systems? Is. 167
TORRANCE, JR., HENRY, Discussion, Economy of Combined Compression and Absorption Machines....130, 131, 132, 133, 134, 135, 136
Does a 100-Ton Ammonia Compression Plate Ice-Making Plant or a 100-Ton Absorption Plate Ice-Making Plant Equal in Economy a 50-Ton Compression Machine in Combination with a 50-Ton Absorption Machine, Using the Exhaust Steam of the Compression Machine for Operating the Absorption Machine?.... 126
Transportation of Fruit in Refrigeration, G. Harold Powell.... 82
Under What Conditions Does It Pay to Use a Cooling Tower?.... 171
VOGT, HENRY, Discussion, Pipe Line Refrigeration....51, 52

VOGT, HENRY— PAGE.
Discussion, The "Plate" System and the "Can" System.....64, 66
Discussion, The Refrigeration of Perishable Food Products.....76, 77
VOORHEES, GARDNER T., Discussion, Brine vs. Direct Expansion in Plate Ice-Making Plants.....165, 166
Discussion, Economy of Combined Compression and Absorption Machines.....131, 133, 134, 135
Discussion, Is Ammonia Gas Inflammable?.....176, 178
Discussion, Is Top Expansion or Bottom Expansion Best in Can Freezing Systems?..... 167
Discussion, Pipe Line Refrigeration.....47, 52
Discussion, The "Plate" System and the "Can" System..... 64
Discussion, The Practical Value of Indicating the Ammonia Compressor.....143, 144, 145, 149, 152
Discussion, Under What Conditions Does It Pay to Use a Cooling Tower? 173
WILLIAMS, L., Discussion, Pipe Line Refrigeration..... 53
Discussion, The Transportation of Fruit in Refrigeration..... 92